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Chairman-elect............GERTRUDE L. WARD, Earlham College, Richmond, IN 47374

Microbiology and Molecular Biology

Chairman................HAROLD EDDLEMAN, Box 378, Route 1, Palmyra, IN 47164

Chairman-elect............DAVID C. MADSEN, Lobund Laboratory, University of Notre Dame, Notre Dame, IN 46556

Physics

Chairman................ROBERT E. HALE, Physics Department, Huntington College, Huntington, IN 46750

Chairman-elect..........ELMER NUSSBAUM, Physics Department, Taylor University, Upland, IN 46989

Plant Taxonomy

Chairman........ORLAND J. BLANCHARD, Department of Biology, Earlham College, Richmond, IN 47374

Chairman-elect........VICTOR RIEMANSCHNEIDER, Department of Biology, Indiana University-South Bend, South Bend, IN 46614

Science Education

Chairman..........Harold H. Jaus, Department of Education, Purdue University, Lafayette, IN 47907

Chairman-elect........Jon R. Hendrix, Department of Biology, Ball State University, Muncie, IN 47306

Soil and Atmospheric Sciences

Chairman......Harry M. Galloway, Department of Agronomy, Purdue University, Lafayette, IN 47907

Chairman-elect....Lawrence A. Schaal, Department of Agronomy, Purdue University, Lafayette, IN 47907

Zoology

Chairman..............Thomas Joseph, Department of Biology, Indiana University-South Bend, South Bend, IN 46615

Chairman-elect......John O. Whitaker, Jr., Department of Life Sciences, Indiana State University, Terre Haute, IN 47807

COMMITTEES APPOINTED BY THE PRESIDENT

(The President and President-Elect are *ex officio* members of all committees.)

ACADEMY FOUNDATION

William A. Daily, Chairman ... (1976)	The Lilly Research Labs. Eli Lilly and Company Indianapolis, IN 46206
Clyde R. Metz .... (1977)	Department of Chemistry Indiana Univ.-Purdue Univ. 1125 East 38th Street Indianapolis, IN 46205

BONDING COMMITTEE

Earl A. Holmes, Chairman.... (1976)	Department of Biology St. Mary's College Notre Dame, IN 46556
Robert M. Brooker .... (1976)	Department of Chemistry Indiana Central College Indianapolis, IN 46227

RESEARCH GRANTS COMMITTEE

Kenneth E. Nichols, Chairman (1976)	Valparaiso University Valparaiso, IN 46383
Robert M. Brooker .... (1977)	Indiana Central College Indianapolis, IN 46227
Charles M. Kirkpatrick ...... (1978)	Department of Forestry and Conservation Purdue University West Lafayette, IN 47907

Donald R. Brannon (1979)	Lilly Research Labs. Eli Lilly and Company Indianapolis, IN 46206
Ralph A. Llewellyn (1980)	Department of Physics Indiana State University Terre Haute, IN 47809

EXECUTIVE COMMITTEE

Barnes, W. B.
*Behrens, O. K.
Blanchard, O. J.
Boneham, R. F.
Burden, S. L.
Burkholder, T. J.
Burton, L.
Cook, D. J.
Cooper, R. H.
Cory, W. A.
Crovello, T.
Daily, F. K.
*Daily, W. A.
*Day, H. G.
Dineen, C. F.
Eberly, W. R.
Eddleman, H.
*Edington, W.
Ellis, L. F.
Galloway, H. M.
Giorgini, A.
*Girton, R. E.
*Guard, A. T.
*Guthrie, F. A.
*Haenisch, E. L.
Hale, R. E.
Holmes, E. A.
*Hopp, W. B.
Jackson, M. T.
Jaus, H. H.
*Johnson, W. H.
Joseph, T.
Kaufman, K.
Knapp, V. R.
*Lilly, E.
*Lindsey, A. A.
*Markle, C. A.
Marks, G. C.
Meiser, J. H.
*Mellon, M. G.
*Meyer, A. H.
*Michaud, H. H.
*Morgan, W. P.
Moulton, B.
Munsee, J. R.
Nichols, K. E.
*Patton, J. B.
*Postlethwaite, S. N.
*Powell, H. M.
Rivers, R. H.
*Schmelz, D. V.
Swartz, B. K.
St. John, P. A.
Van Atta, R. E.
*Wayne, W. J.
*Weaterwax, P.
Weber, N. V.
*Welch, W. H.
Whitaker, J. O.
Winslow, D. R.
*Youse, H. R.

*Past President of Academy

BUDGET COMMITTEE

President—Donald J. Cook
President-Elect—Clarence F. Dineen
Retiring President—John B. Patton
Secretary—Robert E. Van Atta
Treasurer—Stanley L. Burden
Editor—Benjamin Moulton
Director of Public Relations—Walter A. Cory, Jr.
Chairman, Library Committee—Lois Burton
Chairman, Program Committee—Gayton C. Marks
Director, Youth Academy—Robert H. Rivers
Chairman, Youth Activities Com.—Donald R. Winslow
Chairman, Science & Soc. Com.—Otto K. Behrens
Chairman, Academy Foundation—W. A. Daily
Research Grant Committee—Kenneth E. Nichols

Academy Representative to A.A.A.S. Section and Delegate to A.A.S.

WILLIS H. JOHNSON (1974-77)	Department of Biology Wabash College Crawfordsville, IN 47933

Auditing Committee

TIMOTHY J. BURKHOLDER, Chairman	Biology Department Taylor University Upland, IN 46989
A. GILBERT COOK	Department of Chemistry Valparaiso University Valparaiso, IN 46383

Youth Activities Committee

DONALD R. WINSLOW, Chairman	School of Education Indiana University Bloomington, IN 47401
KARL L. KAUFMAN, Coordinator of Science Fairs	Butler University Indianapolis, IN 46208
ROBERT H. RIVERS, Director Junior Academy of Science	Department of Education Purdue University Calumet Campus Hammond, IN 46323
WALTER A. CORY, JR., Director Indiana Science Talent Search	School Science Coordinators Office Morrison Hall 103 Indiana University Bloomington, IN 47401
F. KEITH AULT	Department of Chemistry Ball State University Muncie, IN 47306
JERRY M. COLGLAZIER	Office of State Superintendent of Public Instruction 120 West Market Street Indianapolis, IN 46204
FLOYD CONARD	Westside High School Ninth and Gerry Streets Gary, IN 46402
KEITH HUNNINGS	New Haven High School 900 Prospect Avenue New Haven, IN 46774
GERALD KIRKMAN	North High School 2319 Stringtown Road Evansville, IN 47711
WILLIAM LUMBLEY	Bloomington High School-South 1965 South Walnut Bloomington, IN 47401

JOHN C. MOODY	Division of Education Indiana University Southeast P. O. Box 679 New Albany, IN 47150
MARY J. PETTERSEN	Oliver P. Morton High School 6915 Grand Avenue Hammond, IN 46323
VIRGINIA RHODES	East Noble High School Kendallville, IN 46755

Library Committee

LOIS BURTON, Chairman	Indiana State Library Indianapolis, IN 46204 Phone: 317-633-6425
NELLIE M. COATS	Indiana State Library Indianapolis, IN 46204
W. R. EBERLY	Department of Zoology Manchester College North Manchester, IN 46926
ELI LILLY	5807 Sunset Lane Indianapolis, IN 46208

Program Committee—Chairman

GAYTON C. MARKS	Department of Biology Valparaiso University Valparaiso, IN 46383

Publications Committee

MARION T. JACKSON, Chairman	Department of Life Sciences Indiana State University Terre Haute, IN 47809
WM. B. BUNGER	Department of Chemistry Indiana State University Terre Haute, IN 47809
LOIS BURTON	Indiana State Library Indianapolis, IN 46204
GALE M. CRAIG	Guide Lamp Division Anderson, IN 46011
WALTER A. CORY, JR.	School Science Coordinators Office Morrison Hall 103 Indiana University Bloomington, IN 47401
WM. R. EBERLY	Department of Zoology Manchester College North Manchester, IN 46962
VIRGINIA R. FERRIS	Department of Entomology Purdue University West Lafayette, IN 47907

Wendell F. McBurney .... Office of Sponsored Programs
Indiana-Purdue University
355 North Lansing Street
Indianapolis, IN 46202

Wilton N. Melhorn .... Department of Geosciences
Purdue University
West Lafayette, IN 47907

Benjamin Moulton .... Department of Geography and Geology
Indiana State University
Terre Haute, IN 47809

John F. Pelton .... Department of Botany
Butler University
Indianapolis, IN 46208

Fellows Committee

Benjamin Moulton (1976),
Chairman .... Department of Geography and Geology
Indiana State University
Terre Haute, IN 47809

Thomas R. Mertens (1976) ..... Department of Biology
Ball State University
Muncie, IN 47306

John A. Ricketts (1976) .... Department of Chemistry
DePauw University
Greencastle, IN 46135

Russell K. Stivers (1976) ...... Department of Agronomy
Purdue University
West Lafayette, IN 47907

Charles E. Wier (1976) .... Indiana Geological Survey
611 North Walnut Grove
Bloomington, IN 47401

Richard L. Conklin (1977) ... Department of Physics
Hanover College
Hanover, IN 47243

James B. Cope (1977) .... J. Moore Museum
Earlham College
Richmond, IN 47374

Paul H. Gebhard (1977) ...... Institute for Sex Research
Indiana University
Bloomington, IN 47401

W. H. Headlee (1977) .... Department of Preventive Medicine
I. U. Medical Center
1100 West Michigan Street
Indianapolis, IN 46202

Wm. R. Eberly (1978) .... Department of Zoology
Manchester College
North Manchester, IN 46962

Robert E. Gordon (1978) ...... Office of Advanced Studies
Notre Dame University
Notre Dame, IN 46556

Robert D. Miles (1978) .... School of Civil Engineering
Purdue University
West Lafayette, IN 47907

B. Elwood Montgomery (1978) .. Department of Entomology
Purdue University
West Lafayette, IN 47907

John F. Pelton (1978) .... Department of Botany
Butler University
Indianapolis, IN 46208

Resolutions Committee

Wm. A. Daily, Chairman ...... Eli Lilly and Company
Indianapolis, IN 46206

Howard R. Youse .... Department of Botany
DePauw University
Greencastle, IN 46135

William G. Kessel .... Department of Chemistry
Indiana State University
Terre Haute, IN 47809

Invitations Committee

Philip A. St. John, Chairman . Department of Zoology
Butler University
Indianapolis, IN 46208

Paul R. Quinney .... Department of Chemistry
Butler University
Indianapolis, IN 46208

Necrologist

Fay K. Daily .... 5884 Compton Street
Indianapolis, IN 46220

Parliamentarian

Howard R. Youse .... Department of Botany
DePauw University
Greencastle, IN 46135

Science and Society Committee

Otto K. Behrens (1978),
Chairman .... 4225 Sunrise Road
Indianapolis, IN 46208

Austin W. Fergusson (1976) .... Merry Lea Environmental Center
P.O. Box 263
Wolf Lake, IN 46796

Geraldine M. Huitink (1976) .. Department of Chemistry
Indiana University-South Bend
South Bend, IN 46615

Willis H. Johnson (1976)	Department of Biology Wabash College Crawfordsville, IN 47933
Jerry J. Nisbet (1976)	Office of University Evaluations Ball State University Muncie, IN 47306
Harry G. Day (1977)	Department of Chemistry Indiana University Bloomington, IN 47401
Robert E. Henderson (1977)	Indianapolis Center for Advanced Research, 1300 West Michigan St. Indianapolis, IN 46202
Ralph A. Llewellyn (1977)	Department of Physics Indiana State University Terre Haute, IN 47809
Howard R. Youse (1977)	Department of Botany DePauw University Greencastle, IN 46135
Robert Menke (1978)	St. Henry Road Huntingburg, IN 47542
Clyde R. Metz (1978)	Department of Chemistry Indiana Univ.-Purdue Univ. 1125 East 38th Street Indianapolis, IN 46205
Robert D. Miles (1978)	Department of Civil Engineering Purdue University West Lafayette, IN 47907
John B. Patton (1978)	Indiana Geological Survey 611 North Walnut Grove Bloomington, IN 47401

Membership Committee

Clarence F. Dineen, Chairman	Department of Biology St. Mary's College Notre Dame, IN 46556

Corporation Membership:

Otto K. Behrens, Ad Hoc Dir.	4225 Sunrise Road Indianapolis, IN 46208
Walter A. Cory, Jr.	School Science Coordinators Office Morrison Hall 103 Indiana University Bloomington, IN 47401

Institutional Membership:

Wm. B. Hopp, Ad Hoc Dir.	Indiana State University Terre Haute, IN 47809
Frank A. Guthrie	Rose Hulman Institute Terre Haute, IN 47803

Emeritus Membership:
Robert H. Cooper .... R. R. 9, Box 242
Muncie, IN 47302

Club Membership:
Donald R. Winslow, Dir. ...... Indiana University
Bloomington, IN 47401

SPECIAL COMMITTEES APPOINTED BY THE PRESIDENT

Biological Survey Committee

Jack R. Munsee, Chairman .... Department of Life Sciences
Indiana State University
Terre Haute, IN 47809

Gayton C. Marks .... Valparaiso University
Valparaiso, IN 46383

David S. Woodruff .... Lilly Hall of Life Sciences
Purdue University
West Lafayette, IN 47907

Johnny W. Reising .... Indiana State University-Evansville
1413 Ewing Street
Evansville, IN 47712

James R. Gammon .... Department of Zoology
DePauw University
Greencastle, IN 46135

Willard F. Yates .... Department of Botany
Butler University
Indianapolis, IN 46208

Frank N. Young, Jr. .... Department of Zoology
Indiana University
Bloomington, IN 47401

Victor Riemenschneider ...... Department of Biology
Indiana University-South Bend
South Bend, IN 46615

Theodore Crovello .... Department of Biology
University of Notre Dame
Notre Dame, IN 46556

Emeritus Member Selection Committee

Robert H. Cooper, Chairman .... R. R. 9—Box 242
Muncie, IN 47302

Winona H. Welch .... DePauw University
Greencastle, IN 46135

Edward L. Haenisch .... Department of Chemistry
Wabash College
Crawfordsville, IN 47933

Howard H. Michaud .... 301 East Stadium Drive
Lafayette, IN 47906

Preservation of Natural Areas Committee

Wm. B. Barnes (1978),
Chairman
Department of Natural Resources
616 State Office Building
Indianapolis, IN 46204

Damian V. Schmelz (1976)
Department of Biology
St. Meinrad College
St. Meinrad, IN 47577

Robert C. Weber (1976)
3649 Algonquin Pass
Fort Wayne, IN 46809

J. Dan Webster (1976)
Department of Zoology
Hanover College
Hanover, IN 47243

George R. Parker (1977)
Department of Forestry and Conservation, Purdue University
West Lafayette, IN 47907

Robert O. Petty (1977)
Department of Biology
Wabash College
Crawfordsville, IN 47933

Richard L. Powell (1977)
Indiana Geological Survey
611 North Walnut Grove
Bloomington, IN 47401

Marion T. Jackson (1978)
Department of Life Sciences
Indiana State University
Terre Haute, IN 47809

Carl H. Krekeler (1978)
360 McIntyre Court
Valparaiso, IN 46383

Victor Riemenschneider (1978)
Department of Biology
Indiana University-South Bend
South Bend, IN 46615

Winona H. Welch (Honorary)
DePauw University
Greencastle, IN 46135

Carrolle Markle (Honorary)
Ashfield, MASS 01330
School Science Coordinators Office

Newsletter

Walter A. Cory, Jr.
Morrison Hall 103
Indiana University
Bloomington, IN 47401

"Speaker of the Year" Selection Committee

Frank A. Guthrie (1976),
Chairman
Department of Chemistry
Rose Hulman Institute
Terre Haute, IN 47803

Harry G. Day (1977)
Department of Chemistry
Indiana University
Bloomington, IN 47401

DAMIAN V. SCHMELZ (1977)	Department of Biology St. Meinrad College St. Meinrad, IN 47577
JOHN A. RICKETTS (1978)	Department of Chemistry DePauw University Greencastle, IN 46135

Academy Representative on Indiana Natural Resources Commission

DAMIAN V. SCHMELZ	Department of Biology St. Meinrad College St. Meinrad, IN 47577

SPRING MEETING

MINUTES OF THE EXECUTIVE COMMITTEE MEETING

April 23, 1976

The meeting was called to order by President Donald J. Cook at 5:15 p.m. in the Game Room of the Entry House, New Harmony Inn, New Harmony, Indiana. The minutes of the Executive Committee and of the General Session of the Fall 1975 meeting were approved.

TREASURER'S REPORT

Treasurer Stanley L. Burden presented a financial report for the period January 1 through April 19, 1976, a summary of which follows:

	Academy Accounts	Administered Accounts	Total
Balance: January 1, 1976	$6,666.36	$15,171.59	$21,837.95
1976 Income	4,628.87	2,978.00	7,606.87
1976 Expenditures	4,050.67	2,156.53	6,207.20
Balance: April 19, 1976	$7,244.56	$15,993.06	$23,237.62

The Treasurer also reported that approximately one-half of the 1976 membership dues have been received. He also presented a numerical analysis of the current membership categories. The Treasurer's report was accepted.

STANDING COMMITTEE REPORTS

Academy Foundation Committee: William A. Daily, Chairman, reported that the John S. Wright Invested Income Account held $7,000 as of March 31, 1976. He also reported that the market value of the Foundation Account was $20,432 and that of the John S. Wright Fund was $565,070, up 20.3 and 11.9%, respectively, since September 30, 1975.

Research Grants Committee: Kenneth E. Nichols, Chairman, reported that $2817 has been granted for nine individual research projects this year.

Representative to Association of Academies of Science (AAS): Willis H. Johnson presented a report including statements of Principles and Objectives of Affiliation with AAAS and a review of the AAAS-AAS Workshop held at the Boston Annual Meeting in response to a request initiated by the Academy Budget Committee at its December meeting. He also summarized the Section X meeting and presented suggestions concerning selection of the Academy representative to AAS and Section X.

Youth Activities Committee: Walter A. Cory reported that 22 finalists in the Indiana Science Talent Search were introduced at Indianapolis on March 12; the eleven winners were awarded Scientific

American subscriptions. He also reported that, of the top 300 entrants in the Westinghouse Science Talent Search, ten were from Indiana.

Newsletter: Walter A. Cory, Director of Public Relations, reported that Newsletter 14 was sent to over 1200 members. He presented the results of the questionnaire on proposed newsletter contents and noted that a second such request will appear in Newsletter 15.

Membership Committee: Clarence F. Dineen, Chairman, presented brief comments on suggestions to maintain and increase Academy membership.

Science and Society Committee: Donald J. Cook, reporting for Chairman Otto Behrens, stated that the Academy provided $380 in support of the report "Indiana Natural Gas: Accommodation to Reality." Two further requests for reports have been received from state agencies.

Biological Survey Committee: Jack R. Munsee, Chairman, stated the formal report of the committee will appear in Volume 85 of *Proceedings* and that the committee is preparing a history of the Biological Survey Committee.

SPECIAL COMMITTEE REPORTS

Emeritus Member Selection Committee: Robert H. Cooper, Chairman, presented the following persons for Emeritus Membership (initial membership year shown in parentheses):

FLORA A. HAAS, Crawfordsville, Indiana (1927)
MILDRED CAMPBELL, Indianapolis, Indiana (1931)
ESTHER K. JORDAN, Kerrville, Texas (1931)
HUBERT M. JAMES, West Lafayette, Indiana (1936)
KENNETH N. CAMPBELL, Indianapolis, Indiana (1938)
ERNEST H. GERKIN, South Bend, Indiana (1951)

Motion: That the persons presented be elected to Emeritus Membership. Seconded and carried.

Preservation of Natural Areas Committee: William B. Barnes, Chairman, reported that three state nature preserves have been dedicated by action of the Natural Resources Commission, bringing the total to 40 preserves containing 6,384 acres. Newly dedicated areas are the Olin Lake, Donaldson Cave, and Virginia Pine-Chestnut Oak Nature Preserves. The dedication of the Dunes Nature Preserve and the Indiana Dunes State Park as National Natural Landmarks in June 1976 was announced.

Representative to Natural Resources Commission: Damian V. Schmelz reported on Commission meetings to examine legislation on flood control and related topics.

Motion: That all Standing and Special Committee reports be accepted. Seconded and carried.

NEW BUSINESS

H. E. McReynolds, President of the Indiana Chapter of the American Fisheries Society, discussed a preliminary research proposal dealing with endangered species. James Gammon supported the proposal by outlining activities in other states with regard to Endangered Species Programs. After considerable discussion, the Executive Committee supported the suggestion that the proposal be formally prepared and submitted to the Research Committee for consideration.

The question of the number and type of copies of *Proceedings* to be published was discussed at length.

Motion: That the order be for 600 paper-bound copies of *Proceedings* for exchange and no fewer than 800 hard-bound copies for members and others entitled to receive copies. Seconded.

Amendment: That the number of hard-bound copies to be published be changed to 700. Seconded and carried.

The amended motion carried.

The meeting was adjourned at 7:40 p.m.

Respectfully submitted,
ROBERT E. VAN ATTA, Secretary

SPRING MEETING

MINUTES OF THE GENERAL SESSION

April 23, 1976

The meeting was called to order by President Donald J. Cook at 10:15 PM in the Entry House of New Harmony Inn, New Harmony, Indiana.

The Secretary of the Academy presented a brief summary of committee reports received by the Executive Committee on April 23, 1976.

President Cook made several announcements concerning the Saturday morning walking tour of New Harmony, the ecology tour of Hovey Lake and Gray's Woods, and the ornithology field trip. He also introduced Program Chairman Gayton C. Marks and the tour and field trip guides.

President Cook recognized John Favinger, Bicentennial Committee Chairman, who introduced the speaker of the evening, Dr. B. Elwood Montgomery, Professor Emeritus of Entomology, Purdue University. Dr. Montgomery presented an extremely informative illustrated lecture entitled "The Life and Times of Thomas Say." The lecture detailed important events in the life of Say, called the Father of American Zoology, and included much of the historical background of New Harmony.

Following Dr. Montgomery's lecture, a short motion picture on New Harmony was shown.

President Cook announced that there would be a brief meeting of the Division Chairmen with the Secretary immediately following the business meeting.

The meeting was adjourned at 11:45 PM.

Respectfully Submitted,
Robert E. Van Atta, Secretary

FALL MEETING

MINUTES OF THE EXECUTIVE COMMITTEE MEETING

November 4, 1976

The meeting was called to order by President Donald J. Cook at 7:15 p.m. in Room 224 of Neils Science Center at Valparaiso University, Valparaiso, Indiana. The minutes of the Executive Committee and of the General Session of the Spring 1976 meeting were approved.

TREASURER'S REPORT

Treasurer Stanley L. Burden presented a financial report for the period January 1, 1976 through October 26, 1976, summarized as follows:

	Academy Accounts	Administered Accounts	Total
Balance: January 1, 1976	$6,666.36	$15,171.59	$21,837.95
1976 Income	8,608.79	6,181.60	14,790.39
1976 Expenditures	5,520.47	5,175.72	10,696.19
Balance: October 26, 1976	$9,754.68	$16,177.47	$25,932.15

The Treasurer's report also indicated that there are 963 paid-up members, including 265 senior members, and 163 unpaid members on file. Applications were received from 80 new members in 1976, while 130 members were dropped for nonpayment of dues. The Treasurer's report was approved.

ELECTED COMMITTEE REPORTS

Academy Foundation Committee. William A. Daily, Chairman, presented the following summary report:

I. *Foundation Account*	
Balance as of September 30, 1975	$ 853.59
Income as of September 30, 1976	1,006.35
Disbursements to Academy	300.00
Transferred to Principal	1,000.00
Cash Balance	559.94
II. *John S. Wright Fund*	
Balance as of September 30, 1975	$ 12,000.00
Income as of September 30, 1976	16,763.57
Cash Balances as of September 30, 1976	3,972.18
Disbursements from Invested Income Account:	
Research Grants	4,317.00
Publication of Proceedings, Volume 84	11,000.00
Indiana National Bank Fee	2,494.00
Cash Balance	924.75
Balance in Invested Income Account	14,000.00
III. *Market Value of All Securities*	$580,102.00

Bonding Committee. No report.

Research Grants Committee. Kenneth E. Nichols, Chairman, reported that 3 research grants totaling $2,060 have been awarded in addition to the 9 proposals totaling $2,817 which were approved at the spring meeting.

The reports of elected committees were approved.

PRESIDENTIAL APPOINTIVE COMMITTEES

Science and Society Committee. Otto K. Behrens, Chairman, briefly reviewed the current activities of the committee. He then introduced Ralph A. Llewellyn, chairman of the *ad hoc* panel appointed to prepare the First Annual Report to the Academy. Mr. Llewellyn presented the 31-page report entitled "Indiana Energy 1977—A Status Report with Suggestions for Policy Action" and briefly summarized the document, which is the result of discussions among the panelists, their review of pertinent literature, and their collective scientific judgments. The report includes discussion on electricity, solar energy, natural and liquefied petroleum gases, crude oil, and coal; it also includes suggestions for policy considerations by the State of Indiana.

In approving this report, a truly significant development in the activities of the Indiana Academy of Science, the Executive Committee reaffirmed the recommendations of the Science and Society Committee with regard to the distribution and dissemination of this and future reports of the committee (see Minutes of the Executive Committee Meeting, October 30, 1975).

Representative to AAAS and AAS. No report.

Auditing Committee. No report.

Youth Activities Committee. Walter A. Cory, reporting for Chairman Donald R. Winslow, presented a status report on the activities of the three youth activity programs sponsored by the Academy: the Science Fair Program, the Science Talent Search, and the Indiana Junior Academy of Science.

Eleven Regional Science Fairs were held last year; 22 state finalists and their sponsoring teachers made the trip to Denver to participate in the International Science and Engineering Fair; over 200 organizations contributed financial support for this trip. The 22 student representatives received a total of 38 awards—a record for any state delegation in any year!

The 29th Annual Indiana Science Talent Search produced 57 participants, 22 of which were chosen to appear in the honors program; 8 of these won national honors in the Westinghouse National Science Talent Search and one, Stephen J. Budak of Marquette High School, Michigan City, was declared a national winner (one of the top 40 in the country). Eleven of the 22 state finalists were designated as winners.

Robert H. Rivers, Purdue University, Hammond, has succeeded Lawrence Poorman as Director of the Junior Academy, which meets in Christ College of Valparaiso University this year.

The Youth Activities Committee strongly supports the request to the Academy, to be presented subsequently, for support of annual scholarships.

Library Committee. Donald J. Cook, presenting the report of Lois Burton, Chairwoman, reported that Volume 85 of *Proceedings* will be in the mail very soon, and that exchange arrangements have been made with five additional organizations in Argentina, Brazil, Germany, and Spain. Seventy-nine new journals, received in exchange, have been added to the collection. The Academy library's bibliographic records is now a part of the Ohio College Library Center (OCLC) computer-based network for furnishing on-line union catalog information to more than 700 libraries. The building expansion program of the State Library provides for relocation of the Academy library and greatly increases space available to it.

Publications Committee. Marion Jackson, Chairman, reported that 700 bound copies are included in the Volume 85 printing run. He also reported that *Natural Features of Indiana* has been reprinted by the University of Notre Dame Press, from which it may be ordered. Manuscripts for Monograph IV are being considered.

Program Committee. Gayton Marks, Chairman, made several announcements pertinent to operations during the current meeting.

Newsletter and Public Relations. Walter A. Cory, Director, announced that the next edition of the Newsletter would be completed in mid-November. He requested that information on address changes be passed on to the Secretary, the Treasurer, or the Newsletter editor. He also announced that a questionnaire on Newsletter and other Academy functions would be available at the registration desk during the meeting.

Membership Committee. Clarence F. Dineen, Chairman, made several comments on the annual gain and loss of members and suggested that the committee analyze membership trends during the coming year.

Fellows Committee. Benjamin Moulton, editor of *Proceedings*, presented the first copy of Volume 85 to President Cook. As Chairman of the Fellows Committee, Mr. Moulton made the following motion:

Motion: That the following persons, recommended by the Fellows Committee, be elected as Fellows of the Academy:

Torsten K. E. Alvager
Thomas A. Cole
Norville M. Downie
Harry M. Galloway
M. E. Hodes
Malcom E. Hults
Marion Jackson
Ralph A. Llewellyn
Lawrence E. Poorman
Carl C. Sartain
Robert E. Van Atta
John O. Whitaker, Jr.

Seconded and *carried.*

Resolutions Committee. No report.

Invitations Committee. Philip A. St. John, Chairman, reported that the sites for the next two fall Academy meetings are: 1977—Indiana

University-Purdue University-Indianapolis, 1978—Anderson College. An invitation was extended to the Academy to meet at Manchester College in 1979. The Academy will entertain invitations for 1980 and 1981.

Necrologist. No report.

Parliamentarian. No report.

The reports of presidential appointive committees were approved.

SPECIAL COMMITTEE REPORTS

Biological Survey Committee. Jack R. Munsee, Chairman, reported that the committee report for Volume 85 of *Proceedings* includes 55 titles representing 14 biotic groups for the period 1974-75. The committee is preparing a historical review of the committee from 1891 through 1976. Theodore Crovello presented brief reports of the two sub-committees: Flora Indiana and Endangered Plant Species.

Emeritus Member Selection Committee. Robert H. Cooper, Chairman, reported that no applications for Emeritus status were received since the spring meeting.

Preservation of Natural Areas Committee. William B. Barnes, Chairman, reported that one more nature preserve—Scout Mountain Nature Preserve, a 40-acre tract located in Harrison County—has been dedicated by the Natural Resources Commission. The total is now 41 nature preserves containing 6,430 acres. Two other areas are in various stages of acquisition or dedication.

Speaker-of-the-Year Committee. Damian V. Schmelz, reporting for Frank A. Guthrie, Chairman, announced that Dr. Derek A. Davenport, Professor of Chemistry at Purdue University, had been selected as Speaker-of-the-Year and and would deliver the lecture at the General Session of the Academy.

Representative on Natural Resources Commission. Damian V. Schmelz reported on the Commission's activities for the year, including the following: The 1977-79 Budget request for the Department of Natural Resources is the largest ever submitted; the Indiana State Park System has shown a 14% attendance increase during the past year compared with a national average of 3.2%; monthly meetings of the Commission involve discussion and decision on about 75 individual items dealing with the use of the State's natural resources: land, water, minerals, forests, wildlife, and State properties. He also briefly reviewed legislative recommendations of the Commission.

The reports of the special committees were approved.

The Nominations Committee, John B. Patton, Chairman, submitted the following slate of nominees for presentation before the General Session of the Academy:

President:	CLARENCE F. DINEEN—1977
President-Elect:	JERRY J. NISBET—1977
Director of Public Relations:	WALTER A. CORY, JR.—1977-78

Academy Foundation: .... WILLIAM A. DAILY—1977-78
Bonding Committee: .... ROBERT M. BROOKER—1977
EARL A. HOLMES—1977
Research Grants Committee: .... MARK RESHKIN—1977-81

The slate of nominees was approved by the Executive Committee.

President Cook acknowledged the efforts of the outgoing Chairman of the Research Grants Committee, Kenneth E. Nichols.

NEW BUSINESS

Harry M. Galloway presented a discussion of current problems associated with publication of papers in *Proceedings* dealing primarily with the need for more publication space with higher costs. He also presented several suggestions for alleviation of these problems. After some discussion, the following was presented:

Motion: That all suggestions and recommendations for alleviation of problems associated with the publication of papers in *Proceedings* be transmitted to the Publications Committee for its consideration and appropriate recommendations at the earliest feasible time.

Seconded and *carried.*

Walter A. Cory presented the recommendations of the Youth Activities Committee with regard to the establishment of Academy-financed annual scholarships. By general consensus, the Executive Committee suggested that the Budget Committee address itself to the prospects for financing such a worthy endeavor with the hope that positive accomplishment might be achieved prior to the 1977-78 academic year.

Robert E. Van Atta presented the following constitutional amendment:

Motion: That the Academy amend the constitution, Article VII. MEETINGS. Sec. 1 so as to designate the *annual* meeting as the *spring* meeting, replacing the word *fall* with *spring* and the words *spring* with *fall* where they appear.

That the Academy further amend the constitution by changing the last sentence in Article VI. EXECUTIVE COMMITTEE, COUNCIL, AND BUDGET COMMITTEE. Sec. 4 to read as follows:

"The Budget Committee shall meet during the regular fall meeting of the Academy."

Seconded.

After considerable discussion, the motion to amend was *tabled* until the spring meeting of the Executive Committee in order that Academy officers and Division Chairman might receive input from Academy members on their opinions on this matter. The Secretary was directed to mention this desire in the General Session meeting and to implement an appropriate survey of the membership in a feasible manner.

Theodore Crovello presented a discussion with regard to public responsibilities of biologists and recommendations relative to a second Academy resolution concerning mosquito control in Indiana. After considerable discussion, the matter was referred by common consent to the Resolutions Committee for an appropriate recommendation.

The meeting was adjourned at 11:00 p.m.

Respectfully submitted,
ROBERT E. VAN ATTA, Secretary

FALL MEETING

MINUTES OF THE GENERAL SESSION

November 5, 1976

The Business Session of the 92d Annual Meeting of the Academy was called to order by President Donald J. Cook at 3:15 p.m. in Room 234, Neils Science Center, Valparaiso University, Valparaiso, Indiana.

Professor Fred Kruger, Vice President of Business Affairs, Valparaiso University, welcomed the Academy on behalf of Valparaiso University.

The Secretary of the Academy presented a summary of committee reports and informed the membership of official actions taken by the Executive Committee on April 23, 1976 and on November 4, 1976.

The names of individuals who were elected 1977 Divisional Chairmen and Chairmen-Elect includes:

ANTHROPOLOGY
Chairman: Edward M. Dolan
Chairman-Elect: Russell E. Lewis

BOTANY
Chairman: Gary E. Dolph
Chairman-Elect: Larry R. Yoder

CELL BIOLOGY
Chairman: Ralph Jersild, Jr.
Chairman-Elect: Betty D. Allamong

CHEMISTRY
Chairman: Pang-Fai Ma
Chairman-Elect: Clyde R. Metz

ECOLOGY
Chairman: Thomas S. McComish
Chairman-Elect: Robert B. Priddy

ENGINEERING
Chairman: Milton E. Harr
Chairman-Elect: Ramachandra A. Rao

ENTOMOLOGY
Chairman: Jack R. Munsee
Chairman-Elect: Richard F. Wilkey

GEOLOGY AND GEOGRAPHY
Chairman: Mark Reshkin
Chairman-Elect: Gerald R. Showalter

HISTORY OF SCIENCE
Chairman: Gertrude L. Ward
Chairman-Elect: William W. Bloom

MICROBIOLOGY AND MOLECULAR BIOLOGY
Chairman: Ralph L. Nicholson
Chairman-Elect: Debbie Gayda

PHYSICS
Chairman: Elmer Nussbaum
Chairman-Elect: Carl C. Sartain

PLANT TAXONOMY
Chairman: Victor Riemenschneider
Chairman-Elect: Theodore J. Crovello

SCIENCE EDUCATION
Chairman: Jon R. Hendrix
Chairman-Elect: Stanley S. Shimer

SOIL AND ATMOSPHERIC SCIENCES
Chairman: Lawrence A. Schaal
Chairman-Elect: Stephen A. Justham

ZOOLOGY
Chairman: John O. Whitaker, Jr.
Chairman-Elect: Jackson L. Marr

The Secretary then presented the following motions:

Motion: That the individuals who have applied for membership in the Academy be elected to the types of membership for which they have applied. Seconded and *carried.*

Motion: That the individuals recommended by the Emeritus Member Selection Committee and approved by the Executive Committee be elected to Emeritus Membership. *Carried.*

Motion: That the individuals recommended by the Fellows Committee and approved by the Executive Committee be elected as Fellows of the Academy. *Carried.*

President Cook introduced Ralph A. Llewellyn, Chairman of the *ad hoc* panel of the Science and Society Committee, who summarized the first annual report of that committee entitled "Indiana Energy 1977—A Status Report with Suggestions for Policy Action". Mr. Llewellyn indicated that copies of this report are available to Academy members on request.

Faye Kenoyer Daily presented the Necrologist's report which included the names of ten members:

Edna Banta
Thomas M. Bushnell
Ansel Gooding
William P. Morgan
Marion A. Rector
Jacob Richard Schramm
Russell E. Siverly
Ned Myron Smith
Elmer G. Sulzer
Paul Weatherwax

John B. Patton, Chairman of the Nominating Committee, placed the following slate, previously approved by the Executive Committee, in nomination:

President: .... Clarence F. Dineen—1977
President-Elect: .... Jerry J. Nisbet—1977
Director of Public
Relations: .... Walter A. Cory, Jr.—1977-78
Academy Foundation: .... William A. Daily—1977-78
Bonding Committee: .... Robert M. Brooker—1977
Earl A. Holmes—1977
Research Grants Committee: .... Mark Reshkin—1977-81

The slate was accepted; no nominations were made from the floor.

Motion: That the Secretary cast a unanimous ballot for the slate. Seconded and *carried.*

President Donald J. Cook introduced the Academy Speaker-of-the-Year, Dr. Derek A. Davenport, Department of Chemistry, Purdue University, who presented a superbly entertaining and interesting lecture entitled "From Genesis to the Book of Revelations: 200 Years of General Chemistry Texts Written in America(n)."

The Chairman of the Resolutions Committee, William A. Daily, presented the following resolution which was adopted by the assemblage:

BE IT RESOLVED:

> Members of the Indiana Academy of Science here assembled wish to express our sincere thanks to the president, vice-president and faculty of Valparaiso University for providing us with functional and delightful meeting facilities.
>
> We also thank our program chairman, Dr. Gayton C. Marks, the divisional chairpersons and students for the careful planning of their instructive meetings.
>
> Our Academy "Speaker of the Year", Dr. D. A. Davenport, deserves special recognition for his extremely interesting slide lecture concerning a history of chemical texts and books during the past 200 years.

The meeting was recessed at 5:20 p.m. and was reconvened at 6:30 p.m. with President-Elect Clarence F. Dineen presiding at the annual banquet held in the Great Hall of the Student Union.

Following introduction of the Academy officers and guests at the speakers' table, Dr. Dineen introduced President Donald J. Cook who presented the annual Presidential Address entitled "Chemistry and Culture," an interesting and thought-provoking discussion.

The meeting was adjourned at 9:00 p.m.

Respectfully submitted,
Robert E. Van Atta, Secretary

FINANCIAL REPORT

JANUARY 1-DECEMBER 31, 1976

I. ACADEMY ACCOUNTS

	Income	Budgeted	Expenditure	Budgeted
Dues	$6,585.00	$ 5,950.00		
Reprints: Vol. 84	1,691.53			
85	40.10	3,300.00	$ 2,660.25	$ 3,000.00
Interest	995.16	1,100.00		
Miscellaneous	10.25			
Secretary			465.80	500.00
Treasurer			361.71	400.00
General Office			142.40	250.00
Travel, AAS Dues, etc.			169.90	225.00
Membership Committee			0.00	200.00
Transfer to Administered Accounts			2,750.00	2,750.00
Junior Academy ($300.00)				
Science and Society ($1,000.00)				
Natural Areas (—$500.00)				
Library Binding ($1,000.00)				
Proceedings: Publication ($750.00)				
Proceedings: Mailing ($200.00)				
Publications: Clerical ($0.00)				
President's Fund			100.00	100.00
Newsletter			500.00	500.00
Speaker of the Year Honorarium			500.00	500.00
Program Committee			616.41	1,000.00
Publications Editor's Expenses			518.67	500.00
Youth Activities			71.70	50.00
Biological Surveys Committee			4.00	150.00
Representative to AAAS Meeting			260.73	300.00
Public Relations			57.15	100.00
Section Chairman Expenses			0.00	150.00
CPA Fees for Tax Return Preparation			400.00	500.00
Lawyer's Fees			50.10	100.00
Miscellaneous	$9,322.04	$10,350.00	$ 9,628.82	$11,525.00

II. ADMINISTERED ACCOUNTS

	January 1 Balance	1976 Income	1976 Expenditures	December 31 Balance
Junior Academy	$ 212.92	$ 300.00	$ 457.14	$ 55.78
Science Talent Search	2,315.38	124.10	1,713.93	725.55
Science and Society	1,572.62	1,000.00	647.29	1,925.33
Research	286.60	4,845.00	4,877.00	254.60
Natural Areas	1,026.50	-500.00	0.00	526.50
J. S. Wright Library	134.28	0.00	0.00	134.28
Lilly III Library	2,632.76	0.00	0.00	2,632.76
Lilly V Library	4,513.20	0.00	0.00	4,513.20
Library Binding	—4.45	1,000.00	0.00	995.55
Science Fairs	0.00	0.00	0.00	0.00
Publications:				
Proceedings	148.83	4,764.00	4,866.56	46.27
Mailing of Proceedings	579.43	200.00	0.00	779.43
Monographs	1,253.52	248.50	5.50	1,496.52
Natural Features	0.00	0.00	0.00	0.00
Clerical	500.00	0.00	0.00	500.00
	$15,171.59	$11,981.60	$12,567.42	$14,585.77

III. SUMMARY

	Academy Accounts	Administered Accounts	Total
Balance: January 1, 1976	$6,666.36	$15,171.59	$21,837.95
1976 Income	9,322.04	11,981.60	21,303.64
1976 Expenditures	9,628.82	12,567.42	22,196.24
Balance: December 31, 1976	6,359.58	14,585.77	20,945.35

IV. BANK BALANCES

Upland United Bank, Upland, Indiana	$ 5,967.47
Great Western Savings and Loan, Los Angeles, California	5,626.91
First Western Savings and Loan, Las Vegas, Nevada	9,350.97
	$20,945.35

V. SUMMARY OF TRUST FUNDS

A. Foundation Account (00430-00-0)			
Income cash balance (1/1/76)		$ 809.55	
Total dividends and interest for 1976		1,009.13	
Disbursements for 1976			
Research grants	$ 300.00		
Transfer to principal cash	1,000.00		
	$ 1,300.00	-1,300.00	
Income cash balance (12/31/76)		$ 518.68	$ 518.68
Principal cash balance (1/1/76)		485.94	
Total receipts for 1976		1,000.00	
Total disbursements for 1976		-1,000.00	
Principal cash balance (12/31/76)		485.94	$ 485.94
Market value of investments (12/31/76)			$ 21,882.00
Total value of account (12/31/76)			$ 22,886.62*

*Carrying value is $23,206.53

B. John S. Wright Fund (00430-01-9)

Income cash balance (1/1/76)		$ 687.51	
Total dividends, interest, and other income for 1976		18,989.47	
Disbursements for 1976			
INB fee	$ 2,494.00		
Transfer to 00430-02-8	16,400.00		
Transfer to Principal Cash	0.00		
	$18,894.00	−18,894.00	
Income cash balance (12/31/76)		782.98	$ 782.98
Principal cash balance (1/1/76)		831.77	
Total receipts for 1976		39,287.81	
Total disbursements for 1976		−39,909.25	
Principal cash balance (12/31/76)		$ 210.33	210.33
Market value of investments (12/31/76)			$536,937.80
Total value of account (12/31/76)			$537,931.11*

*Carrying value is $334,253.01

C. John S. Wright Invested Income Account (00430-02-8)

Income cash balance (1/1/76)		$ 190.36	
Total interest for 1976		489.48	
Disbursements for 1976			
Transfers to principal	$ 0.00		
	$ 0.00	$ 0.00	
Income cash balance (12/31/76)		$ 679.84	$ 679.84
Principal cash balance (1/1/76)		472.18	
Total receipts for 1976		30,400.00	
Disbursements for 1976			
Purchase of investments	$22,000.00		
Research grants	4,317.00		
Proceedings, Vol. 85	4,000.00		
	$30,317.00	−30,317.00	
Principal cash balance (12/31/76)		$ 555.18	$ 555.18
Market value of investments			$ 12,000.00
Total value of account			$ 13,235.02

VI. NOTES

Membership Dues:

According to the Treasurer's records, the current status may be summarized as follows:

1019 paid (524 member, 288 senior member, 63 student, 20 family, 15 senior family member, 7 sustaining member, 1 family sustaining, 1 student family member, life (4), honorary (4), emeritus (74), and 19 club members.
111 on file from 1975, but not yet paid for 1976
85 new members for 1976 (included in above totals)
3 previous members reinstated during 1976 (included in above totals)
130 members and clubs dropped for nonpayment of 1975 dues

Dues Structure for 1976:

$ 2.00	for student memberships
5.00	for memberships and club memberships
10.00	for senior memberships
25.00	for sustaining memberships
2.00	additional for family memberships
300.00	for life memberships

150.00-500.00	corporate memberships
50.00-100.00	institutional memberships
1.00	initiation/reinstatement fee ($2.00 for family membership)

Savings:

The treasurer, from the total assets of both Academy and Administered accounts, has maintained sufficient funds in the checking account to pay current bills throughout the year; the remaining funds have been invested in savings certificates.

Certificates redeemed in 1976

NONE

Certificates current

1. (GWSL) $5,000.00 invested at 6.75% April 1975; 31 December value $5,626.91; Maturity at October 1977.
2. (FWSL) $3,000.00 invested at 6.75% October 1976; 31 December value $3,053.46; Maturity at April 1978.
3. (FWSL) $2,000.00 invested at 6.50% April 1976; 31 December value $2,100.47; Maturity at April 1977.
4. (FWSL) $1,000.00 invested at 6.50% June 1976; 31 December value $1,049.26; Maturity at June 1977.
5. (FWSL) $1,000.00 invested at 6.50% June 1976; 31 December value $1,049.26; Maturity at June 1977.
6. (FWSL) $1,000.00 invested at 6.50% June 1976; 31 December value $1,049.26; Maturity at June 1977.
7. (FWSL) $1,000.00 invested at 6.50% June 1976; 31 December value $1,049.26; Maturity at June 1977.

Total $14,977.88

Reprints:

Reprint charges to authors for Vol. 83 are being collected with 1 billing outstanding for $61.55 giving a net profit to the Academy of $123.13 in excess of printing costs. Reprint charges to authors for Vol. 84 are being collected with 2 billings outstanding for a total of $252.12 and will give a net profit to the Academy (1975 and 1976) of $223.81 in excess of printing costs when all bills have been collected. Reprint charges to authors for Vol. 85 are being collected with $2,620.15 outstanding and will give a net profit to the Academy of $225.93 when all bills have been collected.

Attorney Fees:

Ice, Miller, Donadio & Ryan of Indianapolis have been advising the Academy in matters concerning the reprinting and roles of various publications. The executive committee voted at the Fall Meeting of 1973 to delay the transferring of $4,226.87 for attorney fees concerning the tax classification problems to the Academy operating funds from the J. S. Wright fund until these funds are needed for operating expenses.

Publications:

Sales to date during 1976 have been $14.00 for the *Proceedings*, Vol. 84 and $248.50 for Monographs. The total cost of publishing Vol. 85 of the *Proceedings* was $12,866.25 of which the State of Indiana paid $8,000 leaving a balance of $4,866.25 to be paid from Academy funds.

Research Grants:

Funds totaling $4,877.00 have been awarded to: Betty I. Tarnowski (Butler), Anne A. Susalla (St. Mary's), Cindy B. Patterson (I.U.), Lawrence M. Grocki (Ball State), Harold Eddleman (Indiana Biolab), Peter Calengas (I.U.), David F. Brakke (I.U.), Douglas Bauer (DePauw), Scot C. Adams (Purdue), Andreas R. Richter (Earlham), Dona Thampson-Jacob (I.U.), John O. Whitaker (Indiana State), James R. Gammon (DePauw).

VII. BUDGET FOR 1977

The following budget was approved by the Budget Committee at their meeting at the Indiana State Library, Indianapolis, on December 13, 1975:

Academy Accounts

Anticipated Income

Dues, Initiation and Reinstatement Fees (70 @$2, 600 @$5, 300 @$10, 100 @$0)		$ 6,140.00
Interest on Savings		1,300.00
Reprint Charges to Authors		2,886.00
		$10,326.00

Budgeted Expenditures

Secretary		$ 500.00
Treasurer		400.00
General Office		250.00
Officer Travel, AAAS Dues		225.00
Membership Committee		200.00
President's Contingency Fund		100.00
Newsletter		500.00
Speaker of the Year Honorarium		500.00
Program Committee		1,000.00
Publication Editor's Expenses		500.00
Youth Activities Committee		50.00
Biological Surveys Committee (including Endangered Plant Species and Flora Indiana Project Committees)		150.00
Representative to AAAS Meeting		300.00
Reprint Charges to Academy		2,700.00
Public Relations		100.00
Section Chairmen Expenses		150.00
CPA Fees for Tax Return Preparation		500.00
Lawyer's Fees		250.00
Miscellaneous		100.00
Transfers to Administered Accounts		2,923.50
Junior Academy	$1,000.00	
Science and Society Committee	500.00	
Natural Areas Committee	–526.50	
Library Binding	1,200.00	
Proceedings: Publication	750.00	
Proceedings: Mailing	0.00	
		$11,398.50

Endowment Funds

Anticipated Income

IAS Foundation	$ 300.00
J. S. Wright Investment Income	15,500.00
	$15,800.00

Budgeted Expenditures

Bank Fee	$ 2,700.00
Research Grants ($6,000–$350 AAAS)	5,650.00
Publications	
Proceedings, Vol. 86 ($13,750–$8,000 Ind. —$750 transfer)	5,000.00
Monograph #4 ($12,000–$1,500 Wright balance from 1975–$1,200 sales)	(9,300.00)*
	$13,350.00

*Suggest waiting until later for more Wright balance, sales, etc. to justify this.

Restricted Accounts

Anticipated Income

Research Grants Committee (AAAS)	$ 350.00 (part)
Science Talent Search (Tri Kappa)	2,000.00

Publications			
Proceedings	$ 50.00		
Monographs and Nat. Feat.	250.00		
			$ 2,650.00
Budgeted Expenditures			
Research Grants Committee			$ 350.00 (part)
Science Talent Search			2,000.00
Publications			300.00
Proceedings	$ 50.00	(part)	
Monographs	250.00	(part)	
			$ 2,650.00

Respectfully submitted,

Stanley Burden, Treasurer

We, the undersigned, have audited the Treasurer's records for the Indiana Academy of Science for the year 1976 and have found them to be accurate and in order.

March 1, 1977

Timothy J. Burkholder
A. Gilbert Cook

THE INDIANA JUNIOR ACADEMY OF SCIENCE

44th Annual Meeting, November 5, 1976

The 44th annual meeting of the Junior Academy began with a welcome from George Jones, President and Dr. Robert Rivers, Director. At 9:15, students, teachers and sponsors were dismissed to hear paper presentations. This year was the first for a division between papers dealing with the Physical Sciences and papers dealing with the Biological Sciences. This year was also the first for paper presentations in the Junior High Division. At 11:30, everyone adjourned to Dau Hall for lunch and the Junior Academy Meeting. After the meal, George Jones informally asked the clubs to consider nominees for President and Secretary-Elect. At 12:20, George called the Junior Academy Meeting to order. He listed the qualifications for President-Elect and Secretary-Elect as listed in the Constitution of the Indiana Junior Academy of Science. The nominations were then open for the offices of President and Secretary.

PRESIDENT-ELECT

Lori Ellen Rhodes—East Noble High School (Tom Ault—East Noble High); Greg Rondot—Bishop Luers High School (Jamie Oxley—Bishop Luers High); Craig Warner—Morton High School (Mick Maslar—Morton High).

SECRETARY-ELECT

Stacy Fox—East Noble High School (Tom Ault—East Noble High); Jamie Sibbit—Paoli High School (Ann Pfauth—Marquette High).

A motion was made to close the nominations, the motion was seconded. Dr. Rivers then introduced Mr. Dean Christakis from Marquette High School, who was to show a slide presentation of his trip to Sweden for the Nobel Prize Presentations. When he had finished the presentation, Mr. Christakis turned the meeting back to George. George then called the nominators to the podium to list the qualifications of his candidate. The nominators were given a few minutes to write down the candidate's qualifications, as they had not prepared a list before this time. During this time, Dr. Mary Pettersen made an announcement regarding the lunch fee. A few minutes after her announcement, the nominators came to the podium to list the qualifications of the candidates—first for President, then for Secretary. George then called for a representative of the Science Clubs who had paid their Academy dues to cast their delegate vote, when called upon.

RESULTS OF VOTING (President)

Morton—Craig Warner
Paoli—Greg Rondot
Madison—Lori Rhodes
Marquette—Craig Warner
New Haven—Greg Rondot
East Noble—Lori Rhodes
Yorktown—Lori Rhodes
Floyd Central—abstain
Floyd County—abstain
Bishop Luers—Greg Rondot
Bishop Dwenger—Greg Rondot

RESULTS OF VOTING (Secretary)

Morton—Jamie Sibbitt
Paoli—Jamie Sibbitt
Madison—Stacy Fox
Marquette—Jamie Sibbitt
New Haven—Stacy Fox
Bishop Dwenger—Stacy Fox
East Noble—Stacy Fox
Yorktown—Stacy Fox
Floyd County—Jamie Sibbitt
Floyd Central—Jamie Sibbitt
Bishop Luers—Stacy Fox

George turned the meeting over to Dr. Rivers for award presentations, while he and Secretary Cheryl Pauer tallied the votes.

AWARD PRESENTATIONS

Junior Division

First Place
Bradford Beaver—Yorktown Middle School
Wendy Rhodes—East Noble High School
Second Place
Greg Gesler—Madison Junior High
Jamie Sibbitt—Paoli Junior-Senior High
Third Place
Kurt Ehrman—St. John the Baptist (Fort Wayne)
David Johnson—Daltz High School (Muncie)
Tammi Hedges—St. John the Baptist (Fort Wayne)

SENIOR DIVISION—PHYSICAL SCIENCES

First Place
Greg Rondot—Bishop Luers
Patty Wolfe—New Albany
Second Place
John Stark—East Noble
Mike Patterson—East Noble
Third Place
Jamie Oxley—Bishop Luers

SENIOR DIVISION—BIOLOGICAL SCIENCES

First Place
Lori Rhodes—East Noble
Paul Kmak—Marquette
Second Place
Mary Wombles—Floyd Central
John Evans—Floyd Central
Third Place
Bradford Stephens—New Haven

George Jones then announced President-Elect and Secretary-Elect. President—Greg Rondot; Secretary—Stacy Fox. Dr. Rivers offered a closing statement, and Dr. Pettersen then introduced Mr. Davis of the admissions office of Valparaiso University who discussed the qualities of the school. George then declared the meeting adjourned; everyone was free to choose one of the following: A tour of Valparaiso University, either with a guide or on his own; Working with Science computers; Attending the Senior Academy Paper Presentations.

BIOLOGICAL SURVEY COMMITTEE REPORT—1975-76

Jack R. Munsee, Chairman, Indiana State University

Theodore Crovello
University of Notre Dame
James R. Gammon
DePauw University
Morris Levy
Purdue University
Gayton C. Marks
Valparaiso University

Victor Riemenschneider
Indiana University, South Bend
David S. Woodruff
Purdue University
Willard F. Yates, Jr.
Butler University
Frank N. Young
Indiana University

(A, B, or C accompanying title refers to: Publication; Thesis on File; or Work in Progress, respectively.)

Biota:

*1. Haag, B. 1974. Biological magnification of DDT in plants and animals in Jefferson County. B.A. Thesis. Hanover Coll. (B).

2. Helms, Ronald L., and Marion T. Jackson. 1976. A biotic inventory of Dobbs Park Natural Area. Proc. Indiana Acad. Sci. 85:208-216. (A).

Fungi:

1. Fahey, T., and J. D. Schoknecht. Indiana State Univ. Developmental studies of *Coprinus* and its ozanium and oidium states. (C).

2. Hasselbring, T. S., Tansey, M. R., and M. A. Jack. 1975. Fungi associated with growing stalactites. Mycologia 67:171-172. (A).

3. Huber, D. M., and G. R. Anderson. 1976. Effect of organic amendment on snowmold of winter wheat. Phytopathology 66:1028-1032. (A).

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NECROLOGY

Fay Kenoyer Daily, Butler University

Edna Banta

Switzerland County, Indiana	Near Nashville, Indiana
July 19, 1889	April 21, 1975

Edna Banta, teacher and naturalist, was born July 19, 1889, near Vevay, Indiana. She grew up near Madison, Indiana, where her interest in nature developed under the influence of the beautiful countryside.

Her undergraduate college training was obtained at Hanover College and graduate work was done at Indiana University where she earned a Master's degree and did work toward a Ph. D. degree.

Miss Banta began teaching in Indiana at Jefferson County grade schools. She taught also at Madison and Spencer high schools. She went to New Castle in 1947 where she stayed until 1952. There she developed an elementary science program and was science consultant to elementary schools. Her effective teaching methods were the subject of an article in *The Indiana Teacher* (V. 92, p. 216, March, 1948). Of considerable value in this program was the collection of about 900 slides of natural objects. Some of her photographs were accepted for exhibition at the International Salon of Nature Photography in Chicago. She also had a "live library" consisting of a squirrel, rabbit and other pets on loan to classes for study. Nature study trips were also conducted by the teachers to cultivate the ability and accuracy of observation. Miss Banta was a valuable consultant for identification of specimens. She also gave slide talks to garden and civic clubs. One of the most famous topics was the Great Smokies, where she visited. She also walked about 120 miles in Yosemite National Park one summer looking for specimens.

In 1948, Miss Banta went to Santiago, Chile, to teach science in a girl's school for a year. She also served as Park Naturalist at Clifty Falls State Park and McCormick's Creek State Park in Indiana. Her gentleness with animals and care of injured birds and beasts produced a number of charming pets, well-remembered by park visitors and friends.

When the Mary Gray Bird Sanctuary was obtained by the Indiana Audubon Society, Miss Banta became the Resident Naturalist there. The Tulip Popular Trail was laid out and developed by Miss Banta and she made many of the permanent plantings.

In 1962, she left the sanctuary and moved to a home near Nashville, Indiana, where she lived until her death, there, April 21, 1975. She was the subject of an article in the *Indianapolis Times* (December 21, 1962) which mentioned the beautiful decorations which she fashioned from natural materials collected from her property. The wreaths and other objects were on consignment at two shops.

Miss Banta joined the Indiana Academy of Science in 1931 and became an emeritus member in 1967. She served on the Junior Academy Committee in 1951. She presented a paper on the plants of Jefferson County, new or rare, at a paper session in 1935. Representative specimens were sent to the Deam Herbarium and her work is cited in Deam's *Flora of Indiana.*

Unforgettable Miss Banta shared her love of nature with others and enriched their lives by it, a legacy which will benefit many.

THOMAS M(ARK) BUSHNELL

Monticello, Indiana	Lafayette, Indiana
April 5, 1889	January 20, 1976

Dr. Thomas M. Bushnell was a retired professor of Agronomy at Purdue University and died at Lafayette, Indiana, January 20, 1976. He was born in Monticello, Indiana, April 5, 1889. He received a B.S. in Agronomy from Purdue in 1912.

His career began as Soil Surveyor, Bureau of Soils, U.S. Department of Agriculture from 1912 to 1918. In 1917 to 1919, while serving in the aviation section of the U.S. Army Signal Corps, he realized that air photography could be applied to soil survey. He returned to be with the agricultural experiment station at Texas Agriculture and Mechanical College from 1919 to 1921, but came back to Indiana in 1921 to be in charge of soil survey at Purdue's Experimental Station until 1953. He became Emeritus Professor of Agronomy in 1959. He used air photos for mapping Jennings County in 1929, the first entire county survey in the U.S. to be made on air photos.

Prof. Bushnell was head of a land classification unit of the Resettlement Administration from 1935 to 1937. He also supervised land classification units in 1946 to 1947 in Japan and was with the Cornell Air Photo team from 1954 to 1956 in Rangoon, Burma. He did soil surveys in the Dominican Republic in 1951.

Purdue's soil exhibit at the Indiana State Fair promoted soil knowledge by innovations provided by Dr. Bushnell. He developed a simple means of sampling soils, easily stored and preserved, and called the resulting products "micromonoliths". He made available in a kit the cutters, preservatives, glues and cards needed for their preparation. He prepared an electronic board where visitors to the fair could find answers to the soil questions by flashing lights or buzzers. The idea was adapted by state park naturalists for identification of wildlife by visitors.

Dr. Bushnell wrote a *Story of Indiana Soils* published in 1944 by the Purdue Experiment Station. It was so popular that the demand, long after it was out of print, prompted Dr. Bushnell to publish it privately in 1958 and market it by his own company, Peda Products, under the title, *A Story of Hoosier Soils*. He also offered the kits for micromonolith sampling. These were used in 4H projects. Several years ago, the remaining books and kits were presented to Purdue's Agronomy Club for distribution.

Dr. Bushnell joined the Indiana Academy of Science in 1922 and was honored as a Fellow in 1935. He became an emeritus member in 1975. He was a frequent contributor to paper sessions and published papers in the *Proceedings Indiana Academy of Science* on soil survey, aerial photography applied to soil survey, taxonomy, outline of classification of Indiana soils, soil maps, a mystery mound in Lake county, the history of soil science in Indiana 1816 to 1966, etc. He was chairman of the Geology and Geography Division in 1939.

Dr. Bushnell was also a member of the A.A.A.S., Soil Science Society, Soil Survey Association, International Society of Soil Science and Fellow of the Agronomy Society.

Dr. Thomas M. Bushnell died at age 86 after a two-week illness. He had been one of the leaders of thought among an early generation of soil surveyors, and tried to make pedology important and understandable to two generations of Indiana citizens.

ANSEL MILLER GOODING

Seymour, Iowa	Richmond, Indiana
July 12, 1924	March 24, 1976

Dr. Ansel M. Gooding died suddenly at Richmond, Indiana, March 24, 1976. Apparently, he suffered a heart attack after having two earlier attacks. He was 51 years old and was a professor of geology at Earlham College. He was recognized as an authority on the glacial geology of southeastern Indiana and southwestern Ohio. He is credited with 23 publications in an Earlham faculty "Memorial Minute". These include *The Glacial Geology of Southeastern Indiana, Guidebook for Field Conference G, Great Lakes and Ohio River Valley* (1965).

Dr. Gooding was born at Seymour, Iowa, July 12, 1924. His A.B. degree was obtained from Augustana College, Rock Island, Illinois in 1949 where geology was given under the able direction of Dr. Fritioff Fryxell. He served in the U.S. Navy from 1944 to 1946, was summer field assistant on the U.S. Geological Survey in 1948 and geologist with the Missouri Geological Survey in 1950 and 1952. His graduate work was done at Iowa State University where he received an M.S. degree in 1951 under the guidance of Prof. A.C. Trowbridge and a Ph.D. in 1957. When he came to Earlham in 1951 as an assistant professor, much of the work on a doctorate had been completed. It was finished later during a leave of absence.

During work on his dissertation, Dr. Gooding received a grant from the National Science Foundation to help with student assistant expenses. The success of the project led to further N.S.F. grants of hundreds of thousands of dollars for research in geology, soils, chemistry, physics and biology over a period of 20 years benefitting faculty and students in all Science Division Departments.

Dr. Gooding became full professor at Earlham in 1964. He was Chairman of the Geology Department from 1961 to 1973, and clerk of the faculty in 1973. He was an excellent and stimulating teacher and his field trips are recalled by students with pleasure. In 1974, he attended a meeting of the Society of Soil Science in Russia and visited the interesting Alma Ata region in southeastern Russia.

He was also active in community affairs and geological and environmental problems. He was also an active member of the local SPUR group and in 1973 was appointed to the Indiana Senate Committee to investigate environmental quality in Indiana in conjunction with the Indiana State Senate Environment and Ecology Committee.

Dr. Gooding joined the Indiana Academy of Science in 1966. He was a member of the Research Grants Committee from 1973 until death. He was also a member of several other professional societies: Geological Society of America; Fellow, National Association of Geology Teachers; International Association for Quaternary Research; American Quaternary Association; Ohio Academy of Science, Honorary Research Society of Sigma Xi and the informal field excursion group, "Friends of the Pleistocene". He was organizer for some of the field trips for the latter society.

At Dr. Ansel Miller Gooding's unexpected death, Earlham President Franklin Wallen remembered Dr. Gooding as "a man who gave unstintingly of himself to his students, to the study of geology, to the community and his family. His many accomplishments, his firm commitment and warm friendship will be deeply missed by all of Earlham".

DAVID T(RACY) JONES

Near Mount Auburn, Iowa
January 9, 1900

Vinton, Iowa
December 15, 1974

Dr. David T. Jones was born on a farm near Mt. Auburn, Iowa, January 9, 1900. It is a farm that has been in his family for 122 years, bought in 1854 from the government. In 1906, his father became County Superintendent of Schools for Benton County and took his family to live in Vinton, Iowa. It was there that David received his early education until his senior year in high school when he attended Iowa State Teacher's College (now Northern Iowa University) because he had already decided to be a teacher. His interest in natural science and teaching developed early. His father allowed him to attend a summer teacher's institute which he held at Vinton High School. There the boy showed talent in geography and especially enjoyed drawing. Dr. Jones received an A.B. degree in 1923 and an M.S. degree in 1925 from Iowa State University and a Ph. D. degree in 1933 from Indiana University.

His professional career was varied. He was a zoology instructor at Utah State University from 1926 to 1927; director of laboratories at Oregon State University from 1927 to 1928; instructor of biology at Marietta College from 1928 to 1931; associate professor at Utah State University from 1933 to 1945; instructor in a summer institute in Kansas the summer of 1945; professor of physical science and department chairman at Huntington College from 1945 to 1946; assistant professor of physiology at Miami University (Ohio) from 1946 to 1948, associate professor from 1949 to 1957; teacher in the Biology Department of Olivet Nazarene College (Kankakee, Illinois) from 1957 to 1963, professor from 1963 to 1969; and then did independent research after that. He was a scholar and a kind and religious man. He helped young people through school after he became a teacher and began tithing for churches at an early age.

Dr. Jones joined the Indiana Academy of Science in 1931 listing his interests as Zoology, Entomology and Cell Biology. He gave a paper at the 1932 fall Academy meeting on anatomical features of the tiger snail *Anguispira alternata*. The snails were collected at Bloomington, Indiana, and the study was made at the Indiana University Zoology Department. He was an emeritus member at death.

Dr. Jones was also a Fellow of the American Association for the Advancement of Science; member of Iowa, Ohio, and Kansas Academies of Science; Fellow, Utah Academy of Science, Arts and Letters; Historical Society of Iowa and the American Malacological Union. He was honored by election to Phi Beta Kappa and Sigma Xi. He contributed articles to various scientific journals and was co-author of *Mollusca of Utah*, 1929; author of *Practical Exercises in Basic Animal Histology*, 1939 and 1944; and also was author of *The Spinal Cord of Amphioxis*, 1944.

Although Dr. Jones taught out of state most of the years after joining the Indiana Academy of Science, he remained loyal to the society and maintained membership for 45 years. He died of hardening of the arteries December 15, 1974, in Vinton, Iowa, at 74 years of age.

WILLIAM P(ITT) MORGAN

Indianapolis, Indiana	Indianapolis, Indiana
November 17, 1893	January 21, 1976

Dr. William P. Morgan was born in Indianapolis, Indiana, November 17, 1893, spent most of his life in this city and died here January 21, 1976. He was Emeritus Professor of Biology from Indiana Central College and was well known for a successful teaching career and research in hybridization of plants.

His education began in Perry Township grade school and secondary school, Manual Training High School of Indianapolis. Material for botany classes was obtained from the Lenia Elder and Brothers Greenhouse on the southside of Indianapolis where a fascination with the variation in gladioli, roses and freezias grown there led Dr. Morgan to his later research in this field.

Dr. Morgan obtained an A.B. degree from Indiana Central College in 1919. He received an M.A. from Indiana University in 1922, was a Fellow there 1925 to 1926 and received a Ph. D. in Zoology in 1926.

His professional career began as Art Supervisor in the Perry Township Schools, Marion County, Indiana, from 1914 to 1919, and he was part-time instructor of art at Indiana Central College. He became Associate Professor of Biology at Indiana Central College from 1919 to 1926 and was a professor from 1926 to 1959, serving as Head of the Biology Department. He became emeritus professor in 1959, but finally retired in 1965. He was also a lecturer at Indiana University, Indianapolis Extension, from 1927 to 1967. He was honored by receiving an L.L.D. degree from Indiana Central College in 1955 for his excellent teaching and he was also an honored alumnus of Indiana University.

Dr. Morgan joined the Indiana Academy of Science in 1920, and was honored as a fellow in 1930. He presented papers at the fall meetings as early as 1922 and for a number of years on insect cytology and on the variation and hybridization of freezias and gladioli. He gave generously of his time in serving the society in many capacities—especially an all time record of 15 years as treasurer from 1935 to 1950. The state of the economy during these years produced financial difficulties for the Indiana Academy of Science which could have meant the end of the society. However, through the successful efforts of Dr. Morgan to obtain funds and manage them wisely, it survived. He became president in 1951 and also served as assistant secretary in 1926 and for several years thereafter. He served on a number of committees: the committee to arrange A.A.A.S. meetings in Indianapolis for 1937; Fifty Year Index Committee 1945 to 1950; Chairman of the Auditing committee 1952 to 1960; Bonding of the Trustee Committee 1954 to 1958; Trustees of the Academy Foundation Chairman 1964 to 1969 and member 1970 to 1972; Invitations Committee 1963 and 1964 and Nominations Committee in 1952. Dr. Morgan also belonged to the Zoological Society of America and Genetics Society of America.

Dr. Morgan's property on the southside of Indianapolis was a showplace in the spring for the great variety of *Narcissus* blooms and other flowers. He had a greenhouse there where much of his hybridization studies were carried on. He perfected several hybrid roses, one of which, "Swingtime" was patented. During his declining years, he suffered several strokes. After having one in 1971, he no longer could work in the greenhouse, but was nursed and aided in finishing some research by his wife, Ada. His sudden death due to a heart attack ended the career of this fine teacher and valued friend.

MARION A. RECTOR

Cass Lake, Minnesota
December 23, 1907

Chicago, Illinois
November 13, 1974

Mrs. Marion A. Rector was born December 23, 1907, at Cass Lake, Minnesota, but came to Indiana early in life. Her early education was obtained at a grade and high school in Montmorenci, Indiana. She graduated from Ball State University where she also received a Master's degree. She was a science instructor there from 1946 to 1964. She was an efficient and well-liked teacher who particularly enjoyed giving the courses in the local flora. Mrs. Rector joined the Indiana Academy of Science in 1946 and was an emeritus member when she died. She presented a paper at a meeting on the herbaceous plants and shrubs of Christy Woods at Ball State University. Her work is cited in *Natural Areas in Indiana* by Lindsey, Schmelz and Nichols. Mrs. Rector served on the Youth Activities Committee for 1964 and 1966 and was state representative on the committee for the Kappa Kappa Kappa Sorority. She was also a member of the University Club; Sigma Zeta, science honorary; Sewing Club; Alpha Association Chapter of Kappa Kappa Kappa and had been on the board of the Muncie Mission.

After becoming blind and suffering a long illness, Mrs. Rector died at 66 years of age in Chicago, Illinois, November 13, 1974. She had been living there with her daughter.

JACOB RICHARD SCHRAMM

Hancock County, Indiana
February 6, 1885

Indianapolis, Indiana
January 13, 1976

Dr. Jacob R. Schramm was 90 years old when he died January 13, 1976, at Indianapolis, Indiana. He was former Head of the Botany Department of the University of Pennsylvania and Research Scholar in Plant Sciences at Indiana University. He is probably best known for his excellent teaching and the founding of *Botanical Abstracts* later broadened to become *Biological Abstracts*, also for his research on the ecology of black mining wastes and physiology of the algae which earned for him an international reputation.

Dr. Schramm was born in Hancock County near Cumberland, Indiana, February 6, 1885. His education at home by his German parents was invaluable to him in later years. He was bilingual and his father had imparted a knowledge of the trees and wild flowers of his native county. He was well-disciplined and led to appreciate music, literature and art. He attended Shortridge High School at Indianapolis, Indiana, when David Starr Jordan was on the faculty. Young Schramm worked several years to earn money for his further education and entered Wabash College in 1907. His life was influenced very much by the teaching and personality of his botany professor, Mason B. Thomas, whose example was held in esteem. By taking summer courses and extra course work in regular sessions, he was able to obtain an A.B. degree by 1910. He became a Lackland Fellow at Washington University, St. Louis, from 1910 to 1912 and received a Ph. D. in Botany in 1913.

Dr. Schramm's professional career began as an assistant to George T. Moore, director of the Missouri Botanical Garden from 1912 to 1915. From 1913 to 1915, he was also an Instructor of Botany at the Shaw School of Botany, Washington University. From 1915 to 1925, Dr. Schramm taught Botany at Cornell University. While there, he founded *Botanical Abstracts* and was editor from 1921 to 1926. He also served as Executive Secretary of the Division of Biology and Agriculture of the National Research Council from 1922 to 1924. He left Cornell to become editor when *Botanical Abstracts* expanded to become *Biological Abstracts* and served from 1926 to 1937. He then became Professor of Botany at the University of Pennsylvania 1937 to 1955 when he became emeritus professor. During this time (1939 to 1954), he was also Director of the Morris Arboretum. He was then a research scholar at Indiana University in 1956 until death. While there in 1966, his volume on the ecology of black mining wastes was published by the American Philosophical Society. He wrote many botanical papers.

Dr. Schramm joined the Indiana Academy of Science while at Wabash College in 1908 and was a member until 1911 when he moved to St. Louis. His membership was renewed in 1956 when he returned to Indiana University as a research scholar. A paper on endophytic algae was read by title at the 1908 meeting. Dr. Schramm collected algae at Woods Hole Marine Biological Laboratory accompanied by Dr. Thomas of Wabash in the summer of 1909. It was there that he met Dr. George T. Moore, a former Wabash student, with whom he later worked at the Missouri Botanical Garden.

Dr. Schramm belonged to and served several other societies: American Association for the Advancement of Science; Botanical Society of America (secretary, 1918 to 1922; vice president, 1923; president, 1925; recipient of Merit Award, 1969); Philosophical Society (secretary, 1947 to 1953; vice president, 1959; recipient of Franklin Medal, 1952). He was also honored by election to Phi Beta Kappa and Sigma Xi, by receiving the G. Miles Conrad Award in 1967 and the Honorary Degree of Doctor of Science at Wabash University in 1959.

Dr. Schramm was married in 1913 and his wife, Mildred, also obtained a Ph. D. degree at Shaw's Garden. She was active in cancer research and helped found the Little Red Door. The lives of the Schramms were exemplary.

R(USSELL) E(MMETT) SIVERLY

Louisa County, Iowa
December 3, 1913

Muncie, Indiana
February 21, 1976

Dr. Russell E. Siverly was born in Louisa County, Iowa, on December 3, 1913. His undergraduate work was taken at Iowa State Teacher's College where he received a B.A. degree in 1939. He obtained an M.S. degree from the University of Wyoming in 1946 and a Ph. D. degree from Oregon State College in 1956.

His professional career began as a teacher in public schools in Iowa, and he served in the U.S. Army Air Corps from 1942 to 1945. He was an entomologist with the U.S. Public Health Service from 1948 to 1953. He spent summers with the U.S. Public Health Service Technical Development Laboratory at Savannah, Georgia, from 1957 to 1959. He received the rank of Scientist (Reserve) in 1961 and continued as a consultant with the laboratory. He became a member of the Ball State University faculty in 1956 as a professor of health science and was also a member of the Muncie Board of Health for two years. He was honored in 1974 by Ball State University at an awards dinner for the faculty because of his outstanding contributions to the university.

Dr. Siverly's chief research interest was the identification, distribution and control of mosquitos. He had grants from the Indiana State Board of Health, National Science Foundation and Ball State University for his work. He wrote many articles and the books: *Mosquitoes of Indiana* and *Rearing Insects in Schools*. He was working with officials at the Indiana State Board of Health to help prevent an outbreak of encephalitis this last summer. At his death, he was preparing short courses for sanitarians to identify mosquito species, their breeding grounds and methods of control.

Dr. Siverly joined the Indiana Academy of Science in 1956 and was elected fellow in 1961. He was chairman of the Entomology Division for 1961 and was Invitations Committee Chairman for 1962. He presented a study of the life cycle of the mosquito illustrated with color slides at the dinner meeting of the Academy on May 18, 1962. He also presented numerous papers, mostly on mosquito populations, habitat, and as disease vectors at other meetings. He also was a member of the American Association for the Advancement of Science, Entomology Society of America, American Mosquito Control Association; Sigma Zeta and Sigma Xi, science honorary societies; Society of Systematic Zoology and American Public Health Association.

Dr. Siverly was a nationally recognized authority on mosquitoes and control at his death. He died February 21, 1976 in Muncie, Indiana, after a brief illness.

NED M(YRON) SMITH

Indianapolis, Indiana
September 9, 1923

Lafayette, Indiana
January 23, 1976

Dr. Ned M. Smith was a lifelong Hoosier. He was born in Indianapolis, Indiana, September 9, 1923. Following high school, he served during World War II with the U.S. Army Airforce in Europe and Africa from 1942 to 1945. He became a Sergeant and received the Air Medal with Cluster. He retained his interest in aircraft and devotion to country in later years.

His college education was obtained at Indiana University, where he received a B.A. degree in 1949, an M.A. degree in 1955 and a Ph. D. degree in 1962.

He was a geologist with the Industrial Minerals Section of the Indiana Geological Survey from 1950 to 1963. He was visiting faculty member in the Department of Geology, Fresno State College, California, in 1963. He also joined the Purdue faculty that year as an associate geology professor in the School of Civil Engineering. In 1967, he transferred to the new Department of Geosciences, School of Science.

Dr. Smith was essentially a field geologist and was Director of Purdue Summer Geology Field Camp in North Park, Colorado, which he helped locate, organize and operate. His enthusiastic guidance and teaching were appreciated by his students, some of whom suggested establishing the Ned Smith Field Camp Fund which has been done in his memory.

Dr. Smith joined the Academy in 1950 when he was with the Indiana Geological Survey. He reported to the society on a "fossil" cave filling in St. Louis limestone in Putnam County, Indiana. He was a fellow of the Geological Society of America, a member of the American Institute of Professional Geologists, National Association of Geology Teachers, Society of Economic Paleontologists and Minerologists, American Association of Petroleum Geologists and was a Certified Professional Geologist and Geological Consultant.

He wrote numerous publications and file reports on Indiana geology and many confidential consulting reports for the dimension stone and quarry industry.

Dr. Ned M. Smith, 52 years of age, died from a rapidly progressing cancer. The end came January 23, 1976, in Lafayette, Indiana. He taught classes up until a week before his death, so that his passing came with shock and sorrow to his students and colleagues at Purdue.

ELMER GRIFFITH SULZER

Madison, Indiana
July 29, 1903

Sarasota, Florida
February 14, 1976

Born a stone's throw away from the famous "Madison, Indiana, cut" producing the 5.89 per cent railroad grade there, Mr. Elmer G. Sulzer found a natural interest in railroads at an early age. Later, this was expressed in his numerous books and articles on early railroading and the history of abandoned railroads. He attended Indiana University and DePauw University receiving an A.B. degree from DePauw in journalism and music in 1925. He was in business with the Sulzer Brothers in Madison from 1925 to 1926. He served at the University of Kentucky from 1926 to 1952 as band director, public relations director and head of the Department of Radio and Arts. He had also been director of the Kentucky University marching band. In 1949, he earned an M.A. degree in communication research from the University of Illinois while also serving as production director of station WILL in Champaign-Urbana.

While at Kentucky University, he took education to the mountain country of Kentucky by use of battery operated radios in communities with otherwise poor communication systems. He built the first university FM station in the United States.

In 1952, Mr. Sulzer came to Indiana University to organize a department of radio and television of which he became chairman. While there, he fostered a fine radio-television facility and the training center became one of the finest in the United States. He became a leading broadcast educator. He retired from the chairmanship in 1964 and returned full time to research and teaching and became coordinator of Industrial Relations. He established the first broadcast institute for high school students and was a consultant to Australian broadcasters and educators to implement broadcast education in Australian Universities. He became professor emeritus in 1969. He received numerous awards for his broadcasting. One of them is the very distinguished George Foster Peabody Award for an educational series on venereal disease. He was also a Kentucky Colonel, Sagamore of the Wabash, honorary chief of the Lexington, Kentucky, fire department, and was honorary member of the Brotherhood of Railway Trainmen. He was an honorary citizen of Louisville, Kentucky, and one of a small group, Broadcast Pioneers. His biography is included in *Indiana Lives*, *Indiana Authors and Their Books 1917 to 1966* (written by Donald E. Thompson), *Ghost Railroads of Indiana* dust jacket and *Indiana Alumni Magazine* articles.

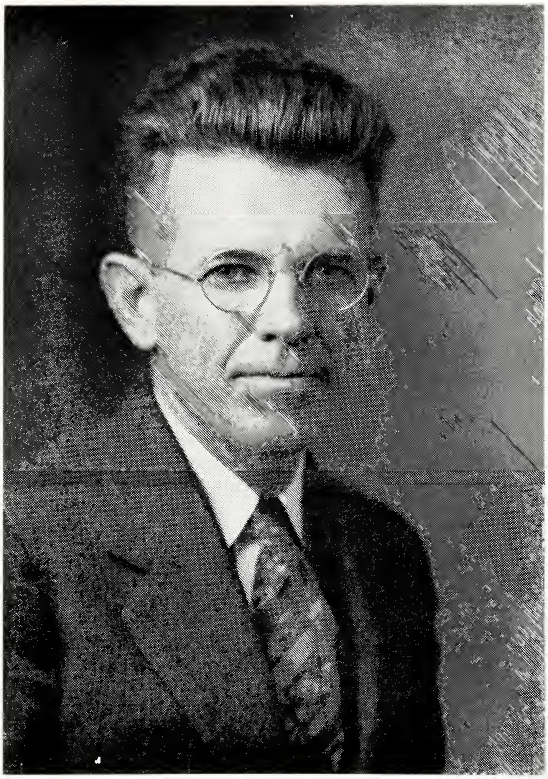
Mr. Sulzer was also vice president and chairman of the board of Electronics Laboratories, Inc. Louisville, Kentucky; and part owner of radio stations in Jeffersonville and Madison, Indiana.

Mr. Sulzer joined the Indiana Academy of Science in 1918 and was an emeritus member when he died. He had presented papers in the Geology-Geography Section on "erosional freaks" of Saluda limestone, remnant monuments near Madison and a paper on railroad history and abandonment in Indiana. He was also active in the National Association of Educational Broadcasters, American Colleges Public Relations Association, Association of Professional Broadcasting Education, Kentucky and Indiana Broadcaster's Associations and a member of other fraternal and professional societies.

Mr. Sulzer became a world-wide authority on abandoned railroads and the causes. He wrote: *Ghost Railroads of Kentucky*, *Ghost Railroads of Indiana* and *Ghost Railroads of Tennessee.* Manuscripts and notes are already with the Indianapolis publisher, Vane A. Jones (personal communication), for *Ghost Electric Railroads of Kentucky and Tennessee*, tentatively scheduled for next year. It is also planned to update the books on abandoned railroads in Kentucky and Indiana. Some of his articles appeared in *Trains*, *The Bulletin of the Railway and Locomotive Historical Society*, *The Kentucky Engineer* and other journals.

Mr. Sulzer was a jazz enthusiast and played the piano in the Indiana University Dixieland Combo. He also played the calliope on Ohio River excursion boats.

This talented, colorful, versatile man died in Sarasota, Florida, February 14, 1976, where he lived after retirement.



PAUL WEATHERWAX

Worthington, Indiana
April 4, 1888

Bloomington, Indiana
October 18, 1976

Dr. Paul Weatherwax was born near Worthington, Indiana, April 4, 1888, and grew up on a farm. At death, he was a world traveler, the foremost international authority on the botanical and ethnological history of the corn plant, specialist in the grasses, morphologist, anatomist and was an emeritus professor from Indiana University.

His A.B. degree was earned at Indiana University in 1914, an A.M. in 1915 and Ph.D. in Botany in 1918. He was an assistant in Botany there from 1913 to 1915 and an instructor from 1915 to 1919. He was an associate professor at the University of Georgia from 1919 to 1921 but came back to Indiana University in 1921. He became a full professor at Indiana University in 1935 and taught there until 1959 when he became professor emeritus.

Dr. Weatherwax was a quiet man disguising his dynamic personality. His scholarship was rewarded many times by grants and awards. He was a Waterman Fellow at Indiana University from 1925 to 1930 and Guggenheim Traveling Fellow from 1944 to 1945 when he went to South and Central America to do research on corn. He was technical assistant in science education on an Indiana University contract when he went to Bangkok, Thailand, from 1957 to 1959. On that trip, he planned to study corn in the hills of Burma in his spare time. Just as recently as last June, he received a merit award for outstanding botanical contributions from the Botanical Society of America.

He traveled more than 150,000 miles seeking the wild ancestor of Indian domesticated corn. He concluded that the original ancestor was extinct, but primitive characteristics were present in several extant varieties. In order to preserve these varieties, a national committee was formed under the auspices of the National Research Council for supervision of the task. According to a news item in 1952, Dr. Weatherwax belonged to this committee. The purpose of the preservation of various corn characteristics was to be able to develop corn adapted to the specific needs of the future, redevelop a resistant corn if blight developed, or redevelop domestic stock if wiped out in a disaster of any kind.

His adventures in the isolated areas of the Andes Mountains in Peru, Equador and Bolivia took him to native corn fields to search for varieties new to science. He was escorted to jails three times during his trips to Central and South America before he could explain his activities to the natives. He also temporarily lost a precious notebook in New Mexico when it was grabbed while he was watching a Pueblo Indian harvest dance. It took much persuasion to recover it. Many trips were taken to Arizona and New Mexico in his quest. He was the author of a hundred or more papers and *Charles Clemon Deam: Hoosier Botanist in Indiana, Magazine of History* (1971), *Indian Corn in Old America* (MacMillan Press, 1954), *The Story of the Maize Plant* and *Plant Biology,* a textbook which has been widely used. His drawings attracted particular interest and there is a permanent collection displayed at the Hunt Botanical Library, Carnegie-Mellon University, Pittsburgh, Pennsylvania.

He was also well known for his advocacy of conservation before its present popularity. Following the precedent at the campus, he helped in planning the preservation and renewal of Dunn Woods, site of the Indiana University Bloomington Campus during the building program. He named and mapped the trees of the campus in *The Wildwood Campus of Indiana University* first issued in 1963 at the urging of Herman B Wells. Dr. Weatherwax was honored June, 1974, at an Indiana University Arbor Day when a marker was dedicated in his honor on the 100th anniversary of the 1874 Arbor Day at I.U.

After Dr. Weatherwax became professor emeritus at Indiana University in 1959, he continued teaching at Franklin College from 1960 to 1963 and at Hanover College in 1966. He also continued research on grass plants. He had access to a section of the Jordan Hall greenhouse at Indiana University, Bloomington campus, for this purpose.

Dr. Weatherwax was a member of the Indiana Academy of Science 63 years, having joined in 1913. He became a fellow in 1922, was Divisional Chairman of the History of Science Division in 1949 and Botanical Division in 1962, treasurer in 1933 and 1934, editor from 1935 to 1940, president in 1941, parliamentarian from 1965 to 1974 and he was a representative on the Council of the A.A.A.S. in 1949. He served on many committees: membership, program, biological survey, resolutions, nominations, publication of the *Proceedings of the Indiana Academy of Science*, research grants, 50-year index, index, *Indiana Scientists* and the special constitution revision committee. His many papers given at Academy meetings reflected a wide range of interests. His early study of microbiology yielded two papers in 1913, the year he joined the Academy, on a parasite of *Spirogyra dubia* and ecological notes on some White River algae. These were notes gathered while he served as an assistant in a sanitary survey done by the Indiana State Board of Health Water Laboratory. In addition, he gave two papers in 1914 on aerating culture collections and some peculiarities of *Spirogyra dubia.* He was an authority on grasses and gave a number of papers at Academy meetings in this field. Many of his papers were on various aspects of his research on corn: morphology, variation and inheritance, origins and some anthropological observations related to corn study. He gave an after dinner speech at an Academy spring meeting in 1932 on his then recent Central American trip. His presidential address was on the Indian as a corn breeder. He gave the invited paper, *Indiana Botany in Retrospect* as part of the Academy participation in the Indiana Sesquicentennial celebration. He gave papers on botanical teaching techniques and one in 1971 on "liquid" endosperm of grasses.

Dr. Weatherwax was a member of several other societies: American Association for the Advancement of Science, Society of American Naturalists, Botanical Society of America (treasurer, vice president), Genetics Society of America, Indiana Historical Society, Phi Beta Kappa, Sigma Xi, New England Botany Club and Society for the Study of Evolution. Numerous biographical sketches and newspaper articles were written about Dr. Weatherwax. The latest was published a few weeks after his death based on an interview obtained in September. This appeared in the *Indiana Alumni Magazine* (November, 1976). In it, it is mentioned that he and his wife had a son, Charles, employee at R.C.A.; Robert, a bacteriologist; and daughter, Helen, first woman editor of the *Indiana Daily Student.*

Dr. Weatherwax died at 88 years of age in Bloomington, Indiana, October 18, 1976. Death came after a prolonged fight with cancer. His wisdom, friendship, long association and service in the Indiana Academy of Science will be sincerely missed.

NEW MEMBERS INDIANA ACADEMY OF SCIENCE—1976

Dr. T. Scott Abney, Dept. Botany & Plant Pathology, Purdue University, West Lafayette, IN 47907

Mr. William James Adam, Bionucleonics Dept., Purdue University, West Lafayette, IN 47907

Mrs. Mary C. Ailor, Dept. of Entomology, Purdue University, West Lafayette, IN 47907

Mr. Gary A. Apfelstadt, Anthropology Laboratory, Indiana State University, Terre Haute, IN 47809

Mr. John B. Bailey, 328 Potomac, Terre Haute, IN 47803

Mr. John E. Bassett, Dept. Biological Sciences, Purdue University, West Lafayette, IN 47907

Mr. David D. Biesboer, Plant Sciences Dept., Jordan Hall, Indiana University, Bloomington, IN 47401

Dr. Sylvia P. Brehm, Dept. of Life Sciences, Indiana State University, Terre Haute, IN 47809

Mr. Warren A. Bruns, Agronomy Dept., Purdue University, West Lafayette, IN 47905

Mr. William Chang, 611 N. Fess St., Apt. E-1, Bloomington, IN 47401

Ms. Sara A. Clavin, Eli Lilly & Co., Indianapolis, IN 46202

Mr. Kenneth J. Collier, Dept. of Chemistry, Ball State University, Muncie, IN 47306

Ms. Cynthia S. Cordera, Dept. Microbiology, I.U. Medical Center, Indianapolis, IN 46202

Dr. Jerry Mallory Davis, Dept. of Geography, Indiana University, Bloomington, IN 47401

Mr. Robert D. Feldt, 607 State Office Bldg., Indianapolis, IN 46204

Miss Laura S. Fisher, Dept. of Geosciences, Purdue University, West Lafayette, IN 47907

Mr. Steven D. Ford, Jasper Polaski Fish & Wildlife Area, Medaryville, IN 47957

Dr. John E. Foster, Dept. of Entomology, Purdue University, West Lafayette, IN 47907

Mr. Tom French, Dept. of Life Sciences, Indiana State University, Terre Haute, IN 47809

Dr. Dorothy Gabel, School of Education, Indiana University, Bloomington, IN 47401

Mr. John A. Gansfuss, Dept. of Geosciences, Purdue University, West Lafayette, IN 47907

Dr. Garland F. Hicks, Jr., Biology Dept., Valparaiso University, Valparaiso, IN 46383

Dr. David Holtz, Holcomb Research Institute, Butler University, Indianapolis, IN 46208

Mr. Russell R. Hyer, 607 State Office Building, Indianapolis, IN 46204

Dr. & Mrs. Zafar Iqbal, Dept. of Physiology, I.U. Medical Center, Indianapolis, IN 46202

Mr. Steven D. Jansen, Energy Resources Center, University of Illinois, Chicago, IL 60680

Mr. Alfred F. Johnson, 3737 South 7th St., Terre South Vigo H.S., Terre Haute, IN 47802

Dr. Stephen A. Justham, Dept. of Geog. & Geol., Ball State University, Muncie, IN 47306

Dr. Kevin R. Kazacos, Dept. Veterinary Microbiol., Pathology & Pub. Health, Purdue University, West Lafayette, IN 47907

Dr. James H. Kellar, 9th & Fess Sts., Bloomington, IN 47401

Mr. Matthew Kelty, Box 369, Dept. of Biology, Notre Dame, IN 46556

Dr. Duncan T. Kennedy, Center for Medical Education, Ball State University, Muncie, IN 47306

Mr. George A. Kinias, 1440 E. 35th Ave., Indiana Vocational Tech. College, Gary, IN 46409

Mr. Gerald W. Kline, Dept. of Anthropology, University of Tennessee, Knoxville, TN 37916

Dr. N. Gary Lane, Dept. of Geology, Indiana University, Bloomington, IN 47401

Mr. Karl H. Langlois, Jr., P.O. Box 723, Monticello, IN 47960

Mr. Thomas Edward Lauer, 1330 W. Michigan, Indiana State Board of Health, Indianapolis, IN 46206

Dr. Morris Levy, Dept. of Biological Sciences, Purdue University, West Lafayette, IN 47907

Miss Mary Lou Lyons, 10101 E. 38th St., John Marshall High School, Indianapolis, IN 46236

Mr. Bradford R. McClarnon, I.U. Student Health #344, Bloomington, IN 47401

Dr. MacLean, Dept. of Biology, Youngstown State University, Youngstown, OH 44555

Mr. Ralph A. Matacale, c/o Lloyd Egler, R.R. 2, Box 156B, Ferdinand, IN 47523

Mr. David Maxwell, 1330 West Michigan St., Indianapolis, IN 46206

Mr. C. Edward Meadows, Dept. of Natural Resources, Ball State University, Muncie, IN 47306

Dr. Kenneth G. Migliorese, 3400 Broadway, Indiana University Northwest, Gary, IN 46408

Mr. John S. Moore, Kendalls Apts. #3, Paoli, IN 47454

Dr. Charles O. Mortensen, Dept. Natural Resources, Ball State University, Muncie, IN 47306

Miss Lucinda Morton, Science Teaching Center, Indiana State University, Terre Haute, IN 47809

Mr. Leonard E. Munstermann, Dept. of Biology, University of Notre Dame, Notre Dame, IN 46556

Mr. Loran S. O'Bannon, Fairway Drive, R.R. 1, Greencastle, IN 46135

Mr. Larry W. Oiler, Wabash College, Crawfordsville, IN 47933

Mr. Paul F. Pedone, Soil Conservation Service, 5610 Crawfordsville Rd., Indianapolis, IN 46224

Mr. Robert R. Priddy, Dept. of Natural Resources, Huntington College, Huntington, IN 46750

Dr. David K. Reed, Fruit & Veg. Insect Res. Lab., USDA-ARS/Box 944, Vincennes, IN 47591

Mrs. Ruth M. Reichmann, R.R. 2, Box 272, Nashville, IN 47448

John L. and Ina C. Ridgeway, 1315 N. Cecil Ave., Greenfield, IN 46219

Mr. David W. Ring, P.O. Box 1918, Harrison Hall, West Lafayette, IN 47906

Mr. John L. Roth, Jr., Dept. of Plant Science, Indiana University, Bloomington, IN 47401

Mr. and Mrs. Garry L. Scholz, Western Materials Co., Box 150, Lafayette, IN 47902

Dr. T. C. Schwan, Dept. of Chemistry, Valparaiso University, Valparaiso, IN 46383

Dr. Donald H. Scott, Dept Botany & Plant Path., Purdue University, West Lafayette, IN 47907

Ms. Janet K. Shaw, 6 N. Chauncey, West Lafayette, IN 47906

Mrs. Gail E. Shew, Dept. of Biology, Ball State University, Muncie, IN 47306

Dr. Toufiq A. Siddiqi, 400 E. 7th St., Indiana University, Bloomington, IN 47401

Ms. Daidee E. Springer, 220 N. Union St., Kokomo Public Library, Kokomo, IN 46901

Mr. Steven W. Stoner, Biology Dept., Ball State University, Muncie, IN 47306

Mr. William E. Tozer, Jr., Biology Dept., Ball State University, Muncie, IN 47306

Mrs. Laura C. Trout, 202 Education Bldg., Indiana University, Bloomington, IN 47401

Dr. Gilbert R. Turpin, 120 East Walnut, Indianapolis Public Schools, Indianapolis, IN 46204

Mr. Mark Alan Verble, David St., Medora, IN 47260

Dr. Carl E. Warnes, Biology Dept., Ball State University, Muncie, IN 47306

Dr. Peter Waser, Dept. of Biology, Purdue University, West Lafayette, IN 47907

Mrs. Margaret R. Watanabe, Dept. of Microbiology, I.U. Medical Center, Indianapolis, IN 46202

Dr. & Mrs. James Watson, Jr., Physics Dept., Ball State University, Muncie, IN 47906

Mr. John M. Wiehe, Zoology Dept., North Dakota State University, Fargo, ND 58102

Mr. James Willut, 835 Laport, Valparaiso, IN 46383

MS. SUE WINDER, Dept. of Anthropology, Indiana University, Bloomington, IN 47401

MR. DENNIS WOLKOFF, Rt. 1, Box 115, The Nature Conservancy, Nashville, IN 47448

MR. ROBERT O. YAGER, Heritage High School, Monroeville, IN 46773

DR. ALAN C. YORK, Entomology Hall, Purdue University, West Lafayette, IN 47907

MR. HANSON L. YOUNG, 2929 Engle Road, Kekionga Jr. High School, Fort Wayne, IN 46809

MR. ROSS B. ZIMMERMAN, Dept. of Zoology, Indiana University, Bloomington, IN 47401

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SCIENCE CLUB, c/o Larry Holler, Yorktown Middle School, Yorktown, IN 47396

INDIANA ENERGY 1977

A STATUS REPORT WITH SUGGESTIONS FOR POLICY ACTION

Committee on Science and Society, Indiana Academy of Science

PREAMBLE

Among the actions taken by the Executive Committee of the Indiana Academy of Sciences at the fall 1975 meeting was the authorization of the Committee on Science and Society to prepare annually, on behalf of the Academy, a report setting forth the status of some aspect of science with significant current societal ramifications, pointing where appropriate to any areas in need of special awareness or action.

Following a review of a number of scientifically-related problems currently the focus of national attention, including several for which the Committee had already initiated activity, the Committee selected Energy as the central theme of this, its first, Annual Report to the Academy. In particular, it was decided to review the condition of Indiana's indigenous energy resources, the current energy consumption within the State, and current thinking regarding future trends against the background of established and *de facto* State policies. Where appropriate, suggestions were to be made for additions to or modifications of policies that concern energy.

During the summer of 1976 the Committee appointed an *ad hoc* panel to prepare the report. This document is the result of discussions among the panelists, their review of pertinent literature, and their collective scientific judgments.

I—Introduction

In 1969, the Bureau of Natural Gas of the Federal Power Commission (FPC) released a report warning of impending supply difficulties with natural gas in the 1970's. This was followed by a second report in 1972 which projected supply and demand for this fuel through 1990 and predicted that domestic production would peak in the nineteen seventies, an event which actually occurred in 1974. The statistical data for the decline of proven reserves were sufficiently compelling that, in 1970, the FPC initiated a round of meetings with national wholesalers of natural gas that led to a series of agreements to curtail deliveries of interstate gas. The major repercussions of these agreements had impact on the large volume sales of gas in the rate category of interruptible contracts with industry. In succeeding years, the curtailment agreements became more stringent, and in the summer of 1975 the FPC and the interstate gas companies announced curtailments in deliveries for the 1975-76 heating season ranging up to 36 percent of anticipated demand. Varying percentages of curtailments, differing geographic areas with regard to proximity to interstate pipelines, and differing mixes of priority users led to projections of grossly inequitable shortages among the states and within individual states. The projected impacts, while widely publicized, turned out for a combination of reasons to be significantly overstated.

The overestimates of natural gas shortages for the 1975-76 heating season tended to obscure in the minds of the public the important fact that the shortage which did occur was very close to that predicted by the FPC Staff Study of 1974 which warned of declines in natural gas supplies of about 5% per year through at least 1980. A similar decline in supplies may well be expected for the 1976-77 heating season.

The public was made dramatically aware of the corresponding situation with regard to crude oil with the embargo initiated by Arab-nation members of the Organization of Petroleum Exporting Countries in October 1973 and the subsequent shortages and rapid escalation of prices for refinery products such as gasoline, heating oils, and diesel fuels. The current adequate, indeed surplus, supplies of petroleum products have led to relaxation of public concern for what is in reality a most serious situation. Even in the presence of surpluses, world crude oil prices have not declined markedly as would be expected if petroleum were traded in a free market. In addition, the proportion of U.S. petroleum consumption that is imported at these higher world prices has risen from about 23% in 1970 to approximately 40% currently, a consequence of steadily declining domestic production. Unfortunately, this falling production will be offset only briefly by the arrival of Alaskan oil, expected to begin late in 1977.

The United States and Indiana are well endowed with coal reserves, but the changing availability of petroleum and natural gas has affected this resource, too. Contract sales at $25 per ton have recently been announced, a figure more than double that of just four years ago. Part of the increase is certainly due to environmental constraints on sulfur emissions, with a resultant shift in demand to low-sulfur coals, but the apportionment is complex, as are the future prospects for utilization of the nation's high-sulfur coal reserves. Economic and technological delays in the implementation of new methods for meeting national air quality standards by the electric utilities, by far the largest single users of Indiana coal, contribute to this uncertainty.

Parallel uncertainties also continue to plague the nuclear power component of the electrical industry which has, in addition, its own unique set of issues. Referenda designed to restrict the development of nuclear energy systems in various ways have recently appeared on the ballot in several states reflecting public uneasiness regarding recurring questions associated with weapons proliferation, radioactive wastes, control of nuclear fuel, and the potential for reactor accidents.

Amidst all this there seems to be an urgent need for us to know where we stand and to decide what our positions on these complex matters will be, both as a nation and particularly as a State. To be sure, in some cases national policies are pre-emptive, but in other areas the stance taken by the State of Indiana will be the most important to the welfare of her citizens and could well play a shaping or even determinant role in the formulation of national energy policies.

The State of Indiana has taken a number of positive positions on energy-related matters. Important among these are the legislatively established policies in the areas of surface mine reclamation and property tax reductions for home solar heating installations. In addition, various State agencies and offices have jurisdiction over, or at least give consideration to, single aspects of the energy situation. They include several divisions of the Department of Natural Resources, the Public Service Commission, the State Board of Health and the related Stream Pollution Control Board and Air Pollution Control Board, the Department of Commerce, and others. Indiana has also taken a leading role in the regional analysis of energy matters in the forum of the Midwest Governors' Conference. However, at this writing Indiana lacks a mechanism for considering total energy needs, methods of filling those needs in the face of reduced supplies in some categories, and development of internal energy sources. Nowhere in the State is there any organization or body that considers the various needs and problems as they relate to one another.

Indiana as a State appears to be doing very little to stimulate development of known or suspected alternate energy sources. In contrast, Kentucky, a major importer of Indiana coal, is supporting major coal gasification and liquefaction projects. Illinois has authorized a $75 million bond issue to fund special efforts at the State level to cope with future energy requirements. In Indiana, however, such matters as whether electrical generating capacity will be increased through expansion at existing sites or installation of entirely new facilities and the siting of proposed nuclear generating facilities are determined solely by the utilities. The State of Indiana takes no official position in such matters or in other energy consumption and development issues.

With the intent of addressing these issues, the two chapters that follow present a brief account of the Indiana energy situation, emphasizing the prospects as they presently exist for various energy alternatives and outlining some suggestions for State policies that, in our judgment, deserve prompt attention.

II—Indiana Energy

Rather than restating energy consumption by consuming sector and fuel or reviewing widely publicized data on declining reserves, the thrust of this chapter is to describe the present situation for the major components of Indiana's energy system, noting in particular the status and future prospects of potential alternatives to those fuels now in common usage.* While our time frame is deliberately vague, the situation will be much as we describe through at least 1980 because the lead times necessary to affect major alterations are typically long. Beyond that time the situation as viewed from the present is progressively less clear.

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* In this section the panel made considerable use of the report "Indiana Natural Gas: Accommodation to Reality" and acknowledges with appreciation the contributions of the task force members who prepared that document. A listing of the task force membership appears in Appendix D.

Energy Conservation

Energy conservation measures offer immediate possibilities to alleviate near-term shortages of domestic fossil fuels. It is generally recognized that the only other means of offsetting such shortfalls is with imported oil, a strategy with obvious problems in view of the nation's current import rate.

Energy conservation, while it is equivalent to a once-only reduction in consumption, offers the potential for substantial fuel savings, dollar economies, and environmental benefits. Unlike other alternatives, the conservation option offers the opportunity for broad public participation and direct, highly visible action on the part of governmental units at all levels with some benefits accruing directly to consumers. On balance, it must also be noted that certain conservation measures might be implemented via price manipulation, a strategy that would increase energy unit costs for consumers. Among the areas where substantial savings can be realized are transportation (e.g., enforced speed limits, tax incentives for smaller engines), residential and commercial uses (e.g., more efficient appliances, improved insulation), and recycling (particularly energy-intensive and petroleum-based materials).

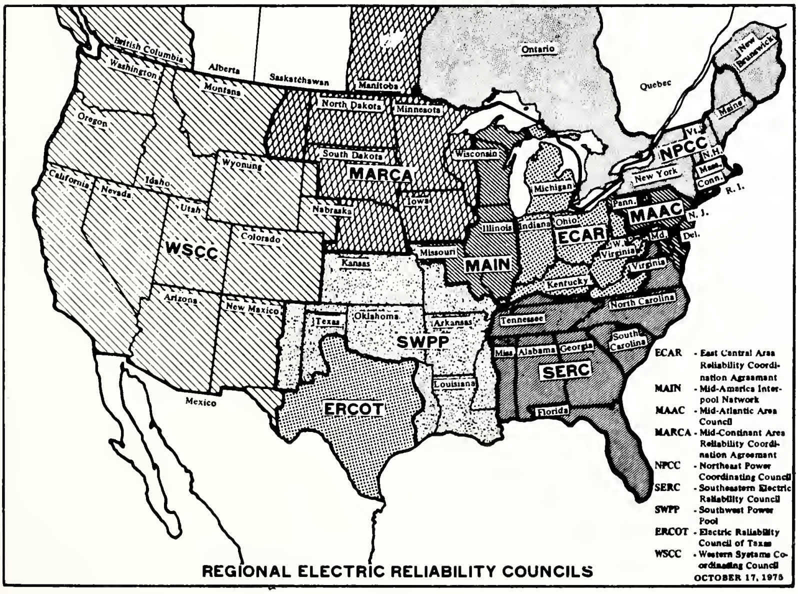
Electricity: Generation Capability and Nuclear Projections

The electric utilities in Indiana are included within the East Central Area Reliability Coordination Agreement (ECAR), one of nine regional reliability councils encompassing nearly all of the power systems of the U.S. and a large fraction of those in Canada. (See Figure 1.) Interconnections between regions are available, so that the future adequacy of electric power in Indiana is likely to depend strongly on the adequacy of regional and national generating capacity. Nevertheless, Indiana policies relative to the construction of new generating capacity will influence the extent to which Indiana can supply its own share of electricity in the future. For example, pioneering State policy regarding the consumptive use of water will have the effect of restricting most new capacity to the Ohio and lower Wabash Rivers.

On a national basis, and therefore on a State basis as well, there is so much uncertainty regarding generation capacity additions and future loads that there can be no assurance that shortages may not begin to develop in the late '70's and early '80's. Current plans for power plant construction during the next decade are expected to result in an annual capacity increase averaging about 5.3% for the 48 contiguous states of the U.S. and about 4.7% for ECAR. But the current load projections for summer load peaks, including the conservatism resulting from the recession, increase at an average rate of about 6.4%, both for the nation and as a whole and for ECAR. Therefore, if these numbers should turn out to be correct, a gradual reduction in reserve capacity will occur from the current 32.5% to 14.7% by 1985. This reduction would inevitably be accompanied by an increasing lack of system reliability and by electrical energy deficiencies with potentially serious economic and social consequences.

Most of the new electric generating capacity that is planned for the next decade is for coal-fired and nuclear plants. Oil-fired capacity is expected to increase slightly and then level off; natural gas-fired generation, primarily in Texas and neighboring states, is projected to decline. The increase in coal capacity averages about 5.8% per year nationally compared with only about 3.3% for ECAR. Projected increases in nuclear capacity average about 17% per year nationally compared with more than 23% for ECAR.

The planned expansion of both coal-fired and nuclear plants should be regarded as lower limits. It would be prudent to increase both, if possible. An excess of capacity would be far less risky to Indiana residents and much easier to correct. Both nuclear and coal-fired capacity expansions are subject to such constraints that a policy of dropping back on one by increasing the other would in all likelihood increase the threat of brown-outs and serious deficiencies of electric power. Accompanying the capacity expansion, consideration should also be given to the introduction of new energy storage technologies and rate structure changes as means of reducing projected increases in peak capacity requirements.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Ontario
Quebec
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Montana
North Dakota
Minnesota
Maine
Oregon
Wyoming
South Dakota
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Vt.
NPCC
N.H.
California
Idaho
Nevada
Utah
MARCA
Michigan
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Conn.
R.I.
Iowa
Nebraska
Pann.
MAAC
N.J.
WSCC
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Illinois
Indiana
Ohio
ECAR
Md.
Del.
Missouri
Kansas
MAIN
W. Virginia
Virginia
Kentucky
North Carolina
Arizona
New Mexico
Texas
Oklahoma
Arkansas
Tennessee
SWPP
South Carolina
Miss
Alabama
Georgia
SERC
Louisiana
Mexico
ERCOT
Florida
ECAR - East Central Area Reliability Coordination Agreement
MAIN - Mid-America Interpool Network
MAAC - Mid-Atlantic Area Council
MARCA - Mid-Continent Area Reliability Coordination Agreement
NPCC - Northeast Power Coordinating Council
SERC - Southeastern Electric Reliability Council
SWPP - Southwest Power Pool
ERCOT - Electric Reliability Council of Texas
WSCC - Western Systems Coordinating Council
REGIONAL ELECTRIC RELIABILITY COUNCILS
OCTOBER 17, 1975

FIGURE 1.

Solar Energy

Indiana's solar flux is sufficiently large to justify continued active development of this resource, especially for use in space heating and air conditioning and in domestic hot water heating. However, the variability of the flux is such that this application will require storage and backup systems. Large scale solar electric power generation will not be attractive in Indiana without major advances in conversion and storage technologies. Table 1 illustrates the average solar flux in Indiana by month.

TABLE 1. *Average Solar Flux on Collector Surface Which is 50° from the Horizontal (BTU/sq ft/day)*

January	1067	July	1581
February	1224	August	1625
March	1438	September	1823
April	1392	October	1682
May	1439	November	1296
June	1493	December	1084

Solar energy in Indiana may not only replace some nonrenewable fuels but, because of the requirement for storage systems, it also has the potential to help alleviate the peak load situation facing the electric utilities. For example, thermal storage systems can be used to "store" air conditioning during the peak demand periods in the summer. Thus, air conditioners in solar homes could be run at night and operated at reduced levels or even turned off during the day when the heaviest electricity demand usually occurs. A similar procedure could be followed for heating systems in the colder months. The procedure in the latter case would be to keep a high percentage of thermal storage capacity in place during the day, even if the solar system is not fully operational. In this manner the solar energy system's storage unit assists in reducing the electrical system's required peak generating capacity.

Because of the high solar flux and the required emphasis on thermal storage, Indiana and neighboring states have the potential to become leaders in solar heating and air conditioning demonstration projects, technology development, and applications. Among the more important areas in which technological development will be important are low-temperature air conditioner systems, solar space heating and domestic hot water systems suitable for retrofitting existing structures, thermal storage systems, auxiliary systems for solar applications such as controls, insulated ducting and low-cost valves, and lower solar collector costs through simpler design, mass production, and on-site construction.

Natural Gas Production in Indiana

Unless major new reserves of natural gas are discovered in Indiana, the State must continue to rely upon gas brought in by long-distance pipelines from the South and Southwest. Present in-state reserves amount to only about 1 percent of the State's annual consumption. Production from Indiana wells last year would have satisfied the State's consumption for 5 hours.

Access to Natural Gas from Out-of-State Sources

Indiana is favorably situated to receive gas from the principal producing regions in the United States, as trunklines from the south and west cross or pass near the State enroute to major consuming regions farther north and east. Proposals now under active review to bring Alaskan gas to the lower 48 states may well result in additional service to the Midwest, including Indiana, from that source. The reduced availability of gas that has been experienced in the past three years and which may be expected to become progressively more acute for the foreseeable future results primarily from declining production at the sources rather than from any inadequacy in the interstate distribution system. A complicating factor, however, is federal price control at the wellhead of gas sold in the interstate market. Some effects of price regulation have been to restrict the availability of gas outside the principal producing states, to encourage use of gas in place of other fuels, and to reduce production. A further complicating factor for Indiana is the varying curtailment levels and differing mixes of priority users across the State leading to inequitable distribution resulting in gas surpluses in some areas and shortages in others. The average 5% annual decline in deliveries to Indiana over the next several years may be expected to amplify those inequalities in the absence of mitigating action by the State or federal government.

Underground Storage of Natural Gas

Large volumes of natural gas stored in porous and permeable sandstone and limestone reservoirs were originally developed to serve as a cushion against fluctuating demand and to permit the local warehousing of gas at times when it was available and the price was low. Indiana has more than 30 such storage reservoirs, and they have performed a valuable service both in making gas more available during periods of high use and in reducing the cost to the consumer. They are based, however, on the concept of gas available in large volume and at low cost. This situation no longer exists, and the storage facilities, which have never been filled to their capacity, are no longer utilized as fully as in previous years. Storage is only effective when there is something to store.

Liquefied Petroleum Gases

Propane and butane (mostly the former) recovered in refining operations are shipped and stored under pressure in liquid form. To a considerable extent they are interchangeable as fuels with natural gas, and they have been the standby fuel for many consumers who have interruptible contracts for natural gas. The liquid form makes them readily transportable, and for this reason they are used extensively for mobile installations, seasonal spot uses (e.g., grain drying), and isolated facilities (cabins, rural residences). Their cost per Btu is high relative to natural gas, and in time of other fuel shortages local supplies may be exhausted.

Underground storage in pressurized excavated space exists at four localities in Indiana and provides some cushion against both high seasonal demand and restricted shipment from refining centers. Product pipelines deliver LPG to the underground reservoirs and surface storage, thus improving delivery capacity in some parts of the state.

Crude Oil Production in Indiana

Indiana's crude oil production is only a small proportion of the State's crude oil consumption (in terms of refinery products), although the exact percentage is difficult to assess because Indiana has a large refining industry, and very large volumes of crude oil are shipped into the State to yield refinery products most of which again go out-of-state. Whatever this ratio may be, Indiana's total known crude oil reserves of 22 million barrels can have little impact on the availability of refinery products within the State. Only significant new oil discoveries can alter this balance, and the discovery rate of recent years does not offer great hope for a change.

Indiana's Access to Crude Oil from Out-of-State

High prices and shortages due to restricted imports would appear to be the only limitations on the availability of crude oil to Indiana's refining industry. Oil enters the State principally via cross-country pipelines and a major and increasing part of the oil is from foreign sources. The crude oil supply to Indiana's largest refinery is nearly 40% foreign, closely paralleling the national situation. This supply is, of course, vulnerable to embargo. Much of the State is not dependent upon Indiana refineries for access to refinery products.

Indiana Coal

Indiana has large reserves of coal (17 billion tons) and substantial annual production (about 25 million tons in 1974 and 1975), but nearly twice as much coal is consumed annually as is produced in the State. Table 2 contains information regarding Indiana coal reserves. The State's consumption profile is contained in Appendix A for both 1974 and 1975. Approximately 5 million tons of Indiana coal are shipped out-of-state annually, which means that over half of the coal consumed is imported. The reasons, in addition to the fact that the State's annual consumption exceeds the annual capacity, are that 1) Indiana ranked 2nd nationally in 1975 in steel production and all metallurgical coking coal must be imported, and 2) the sulfur content in much of Indiana's coals currently requires that they be blended with lower sulfur coals for use in electrical generation. Indiana coal production could be increased about 1 million tons annually for a number of years, a rate already planned by producers for the next 3 to 5 years.

Conjectural Sources of Additional Fuels

Gas from shale and from coal, oil from oil shale, and uranium have received some attention as possible future supplements to Indiana's energy supply.

Natural gas has been produced in modest amounts at a few localities in Indiana from the rock unit called the New Albany Shale, which underlies extensive areas. The Indiana Geological Survey is participating in a broad, multi-state investigation of the shale gas possibilities, supported by the Energy Research and Development Administration. Shale gas wells, if favorable conditions for production are found, will have relatively low individual yield, although the total volume ultimately recovered could be appreciable.

Methane can be removed from bituminous coal in advance of underground mining as a safety measure. The shortage of natural gas combined with increasing prices suggests that demethanization could reach the level of commercial gas production in some regions. The Indiana Geological Survey, in cooperation with the U.S. Bureau of Mines, is testing Indiana coals for methane yield. Early results suggest that the expectable gain in gas supply will be modest even if such development materializes.

TABLE 2. *Recoverable Coal Reserves in Indiana by County, January 1 1974*[1]

County	Strippable	Non-Strippable	TOTAL
Clay	312,770,247	252,366,000	565,136,247
Daviess	137,005,877	119,502,000	256,507,877
Dubois	4,803,000	3,981,000	8,784,000
Fountain Warren	32,446,705	3,603,000	36,049,705
Gibson	—	2,230,905,992	2,230,905,992
Greene	193,619,319	228,181,472	421,800,791
Knox	142,285,000	2,241,335,016	2,383,620,016
Martin	82,771,000	11,000	82,782,000
Owen	49,533,774	—	49,533,774
Parke	9,526,877	29,402,000	38,928,877
Perry	—	28,200,000	28,200,000
Pike	215,199,514	370,015,945	585,215,459
Posey	—	2,870,391,000	2,870,391,000
Spencer	52,140,749	—	52,140,749
Sullivan	290,478,626	3,482,373,446	3,772,852,072
Vanderburgh	—	1,083,454,000	1,083,454,000
Vermillion	37,157,280	295,399,205	332,556,485
Vigo	253,918,457	1,448,483,408	1,702,401,865
Warrick	257,942,501	517,134,269	775,076,770
TOTAL	2,071,598,926	15,205,738,753	17,276,337,679

[1] Modified from Table 6, Page 33, Coal Resources of Indiana, Bulletin 42-I, Indiana Geological Survey (thru Jan. 1, 1965) with Annual Reports of Indiana Bureau of Mines and U.S. Bureau of Mines, 1965 through 1973. Based on recovery by current technology.

The same New Albany Shale that is a possible source for additional natural gas is also classified as a low-grade oil shale and, in addition, contains some uranium. The oil yield in gallons per ton is substantially below the level that is now considered commercial, only 8 to 14 gallons per ton from the richest parts of the formation compared with the minimum yield for economic operation for the Coloado Shales of about 25 gallons per ton. The most radioactive part of the New Albany Shale tested to date is about 0.01 percent U_3O_8 equivalent, in comparison with about 0.2 percent for the current minimum commercial grades. Even this disparity does not tell the whole story, however, as much of the "U_3O_8 equivalent" reflects potassium in the clay minerals, rather than uranium or even thorium. Evaluation of both shale oil and nuclear fuel possibilities must consider, however, the enormous tonnages of New Albany shale that underlie Indiana and other parts of the Midwest.

Coal Conversion

Both gaseous and liquid products that would be satisfactory substitutes for natural gas and certain refinery products can be produced from coal of the type that constitutes Indiana's principal reserves. These methods of utilizing coal have the advantage that sulfur removal from the products is more readily accomplished than from the coal itself, making possible more environmentally sound utilization of Indiana's high-sulfur coals. Processing plants of commercial size are very costly, and only pilot or experimental installations are in operation or under construction at this time, none in Indiana. Both processes entail huge water consumption, and acceptable sites in Indiana would be largely restricted to the Ohio River region. Despite the high costs and other handicaps, coal conversion is probably the best means for the United States to attain a satisfactory level of domestic security in liquid and gaseous fuels. Some research on coal conversion, federally supported, is currently underway within the State.

Low-BTU Gas

Gas that has a BTU content considerably lower than that of pipeline gas (300 to 400 BTU per cubic foot as compared with pipeline natural gas at 1,000 to 1,100 BTU per cubic foot) can be manufactured readily from coal and was indeed the gaseous fuel of the Midwest in the years between the depletion of the early natural gas fields and the coming of the long-distance interstate pipelines from the western and southwestern states and the Gulf of Mexico. The technology is known, and suitable coal is available, for production of low-BTU gas in significant volume, although major production capacity is not in place at this time. Such substitute gas is considered less desirable than natural gas and is less suited to pipeline delivery except over short distances. This lower desirability factor may be expected to prevail until the first cold day after the natural gas supplies become inadequate.

III—Suggestions for Policy

No single answer exists to the problems associated with the impending and projected shortages of energy, whether these be the immediate shortfalls in natural gas or those that will certainly occur among some of the other energy resources consumed in our economy. The potential contributions from many alternative sources must be explored with no guarantees of success. Our situation is such that no possible contributor, the small and improbable as well as the large and apparently obvious, can be ignored without peril. It is also critically important to realize that many potentially significant solutions should receive action now in order to have effects on our State's energy supplies beyond 1980. With these points in mind, the panel makes the following suggestions for policy consideration. These suggestions represent a consensus on each point; being different individuals with differing priority concerns, not all members subscribed to all suggestions.

1. Energy Conservation

While it is not certain to what extent energy consumption may be decoupled from gross national product, good energy conservation practices appear to offer an excellent economical immediate method of counteracting projected shortages of natural gas and petroleum without markedly affecting lifestyles. A considerable relaxation of the conservation efforts of 1973-74 has apparently occurred, and indications are that much of the expected near-term energy shortages and economic impacts could be offset by a renewed and continuing program to educate the public regarding the wisdom of saving energy. A very recent analysis by the International Energy Agency (IEA) shows the U.S. energy conservation effort to be among the worst in the IEA countries. Recognizing that implementation of conservation strategies must be monitored carefully to avoid adverse economic impacts, the State of Indiana could be among the nation's leaders in this area by adoption of the following:

(i) Provide authoritative energy conservation information and an active state-wide program for disseminating it.

(ii) Consider a program of tax incentives to encourage conservation including, but not limited to, rebates for retrofitting existing structures with high efficiency insulation, property tax allowance for similar installations in new structures, and reduced assessments for passenger cars with smaller engines.

(iii) Encouragement of energy-conserving new construction, setting an example by moving to maximize the energy efficiency of State-owned buildings and by requiring that new buildings funded entirely or in part by State funds utilize the best available energy-conserving designs and technologies including solar energy supplementation. Introduction of new building codes such as ASHRAE 90-75 is recommended.

(iv) Development of a technology transfer network throughout Indiana to facilitate the transfer of energy conservation knowledge to end users.

(v) Strict enforcement of the 55-mile-per-hour speed limit on Indiana highways.

(vi) Implementation of appropriate incentive programs to encourage recycling of energy-intensive and petroleum-based materials.

(vii) Thorough consideration of the phase-out of one-way beverage containers as an energy conservation action.

(viii) Analysis of alternative electricity rate structures to determine their conservation impacts.

2. Solar Energy

The potential cited earlier for solar energy utilization within Indiana supports the following recommendations:

(i) Indiana's pioneering solar energy property tax reduction law should be widely publicized in the State.

(ii) The State of Indiana should determine and establish a realistic goal for the percentage of new construction to involve solar heating and air conditioning by 1980, with a similarly developed objective set for the percentage of all space heating and cooling that should be provided by solar means by 1985.

(iii) Solar energy information centers should be developed (perhaps a part of the network suggested in 1. (iv) above). These centers would provide architects, builders, savings and loan associations, banks, industrial and residential consumers, trade unions, and others with technical information on solar energy applications.

(iv) The State should play an active role in attracting demonstration funds for solar energy from ERDA and HUD to Indiana.

(v) Indiana should develop further the existing network of solar monitoring stations for data collections.

(vi) An active State-wide program should be implemented to educate the public on solar energy. This program would include the production of authoritative literature whose major purpose would be to inform the consumer on the following: (a) give consumers enough understanding to permit them to recognize accuracy of performance claims of solar equipment manufacturers; (b) give consumers enough background to make personal decisions in regard to their own best use of solar energy; (c) provide technical information that will make it possible for "do it yourself" individuals to go ahead on their own and build solar collecting equipment.

3. Electrical Power

Announced generating capacity expansion plans within ECAR over the next ten years prompts the following suggestions for policy consideration:

(i) A prudent policy for both Indiana and the nation is to recognize the constraints to building additional coal-fired and nuclear capacity, and to make every effort to resolve the many problems involved in order that the utility companies may find it possible to install more capacity than is currently planned, and to do so with minimal environmental impact.

(ii) Utilities should be encouraged to explore the potential for lower facility construction costs through energy storage installations, e.g., pumped storage, underground compressed air, or thermal storage.

4. Coal

Following completion of the large interstate gas pipelines in the 1950's, Indiana consumers along with those in most of the midwestern and northeastern states responded to economic incentives and shifted a significant portion of their energy consumption to natural gas produced in the South and Southwest. As supplies from those areas begin to decline, it appears that a most important alternative available to the State is its large coal reserves. Gasification to produce both high and low Btu gas from coal offers direct substitution for natural gas. Additional means of utilizing coal efficiently with due recognition of environmental constraints need active study. These points support the following policy recommendations:

(i) The State should make immediate, vigorous efforts to develop gasification projects for both high and low Btu gas at scales sufficient to relieve impending pressures that will surely result as future interstate natural gas curtailments spread more deeply into the Indiana economy.

(ii) The State should carefully consider the advisability of a State tax on all future coal mined. The returns should be applied, under legislative authority, to a trust fund for research, development, and demonstration of gasification, liquefaction, and desulfurization of Indiana coals for use in Indiana homes, businesses, and industries. A one percent tax on Indiana's 1975 coal production of 25,269,000 tons with an average minehead value of $11.25 per ton would raise $2,840,000 for this purpose.

Appendix A

Indiana Coal Consumption—1975

(tons)

In-State Consumer Use of State Coal Production:		
Electric Utilities		17,222,000
Coke & Gas Plants		--------
Retail Dealers		416,000
All Others		2,735,000
Sub-total		20,373,000
Coal Shipped Out-of-State to:		
Michigan	132,000	
Ohio	72,000	
Illinois	386,000	
Wisconsin	871,000	
Minnesota	88,000	
Missouri	402,000	
Georgia	482,000	
Kentucky	1,689,000	
Tennessee	509,000	
Alabama	25,000	
Not Revealable	15,000	
	4,671,000	4,671,000
Total State Production		25,044,000

Appendix A—Continued

Coal Shipped Into State From:		
Pennsylvania	2,040,000	
West Virginia	9,819,000	
W. Kentucky	4,267,000	
Illinois	6,273,000	
Ala., Ga., Tenn.	164,000	
Colorado	2,000	
Wyoming	3,019,000	
Utah	131,000	
Montana, Wash.	840,000	
	26,555,000	26,555,000
State Production Used in State		20,373,000
Total Coal Consumption Used		46,928,000

Consumer Use In State
(Grand Total)

Electric Utilities	28,715,000
Coke & Gas Plants	14,072,000
Retail Dealers	596,000
All Others	3,545,000
GRAND TOTAL	46,928,000

SOURCE: Bituminous Coal and Lignite Distribution Calendar Year 1975, Div. of Fossil Fuels, Ap. 12, 1976, U.S. Dept. of The Interior, U.S. Bureau of Mines

Indiana Coal Consumption—1974
(tons)

In-State Consumer Use of State Coal Production:		
Electric Utilities		15,741,000
Coke & Gas Plants		—
[1] Retail Dealers		153,000
[2] All Others		3,246,000
Sub-total		19,150,000
Coal Shipped Out-of-State to:		
Ohio	347,000	
Illinois	493,000	
Wisconsin	404,000	
Minnesota	106,000	
Missouri	68,000	
Georgia	1,255,000	
Kentucky	1,656,000	
Tennessee	262,000	
Not Revealable	35,000	4,626,000
Total State Production		23,766,000

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[1] "Retail Dealers." Any person (including the retail outlet, branch or department of one who is also a producer, wholesaler, or dock operator), to the extent that he acts in the capacity of a supplier, shipper, or seller of bituminous coal and lignite in any transaction involving a shipment, sale, or sale and delivery to a consumer of broken-bulk bituminous coal and lignite physically handled in a truck, wagon, or other less-than-carload facility, without regard to type of consumer or to the quantity or frequency of delivery. Also, all railroad carload shipments that are delivered to a retail dealer's facilities are to be reported in this category (not including, however, carload shipments that are shipped for his account but not to his plant or facilities.)

[2] "All Others." All consumers of bituminous coal and lignite other than electric utilities, coke and gas plants, retail dealers, railroads, coal mines, and mine employees.

Appendix A—Continued

Coal Shipped Into State From:		
Pennsylvania	1,721,000	
Ohio	31,000	
[3] District 7	3,272,000	
[4] Districts 3-6	160,000	
[5] District 8	6,226,000	
W. Kentucky	3,506,000	
Illinois	6,922,000	
[6] District 13	43,000	
Colorado	13,000	
Wyoming	2,255,000	
Utah	29,000	
[7] Districts 22-23	603,000	24,781,000
State Production Used in State		19,140,000
Total Coal Consumption Used		43,921,000

Consumer Use In State
(Grand Total)

Electric Utilities	25,313,000
Coke & Gas Plants	13,609,000
Retail Dealers	396,000
All Others	4,603,000
GRAND TOTAL	43,921,000

SOURCE: Bituminous Coal and Lignite Distribution Calendar Year 1974, Division of Fossil Fuels, April 18, 1975, U.S. Department of The Interior, U.S. Bureau of Mines

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[3] Specified counties in West Virginia and Virginia.

[4] Specified counties in northern West Virginia and the panhandle of W. Va.

[5] Specified counties in West Virginia, Virginia, Kentucky and Tennessee.

[6] All of Alabama and specified counties in Georgia and Tennessee.

[7] Montana, Washington, Oregon and Alaska.

Appendix B

SCIENCE AND SOCIETY COMMITTEE

DR. OTTO K. BEHRENS (Chairman)
4225 Sunrise Road
Indianapolis, IN 46208

DR. STANLEY L. BURDEN
Box 528
Taylor University
Upland, IN 46989

DR. DONALD J. COOK
625 E. Washington Street
Greencastle, IN 46135

DR. HARRY G. DAY
Department of Chemistry
Indiana University
Bloomington, IN 47401

DR. CLARENCE F. DINEEN
Department of Biology
St. Mary's College
Notre Dame, IN 46556

DR. AUSTIN W. FERGUSSON
326 Federal Building
Ft. Wayne, IN 96802

DR. ROBERT E. HENDERSON
Indianapolis Center for Advanced Research
1219 West Michigan Street
Indianapolis, IN 46202

Appendix B—Continued

Dr. Geraldine Huitink
Department of Chemistry
Indiana University-South Bend
South Bend, IN 46615

Dr. Willis Johnson
Department of Biology
Wabash College
Crawfordsville, IN 46933

Dr. Ralph A. Llewellyn
Department of Physics
Indiana State University
Terre Haute, IN 47809

Dr. Robert Menke
St. Henry Road
Huntingburg, IN 47542

Dr. Clyde R. Metz
Department of Chemistry
I.U.P.U.I.
Indianapolis, IN 46205

Prof. Robert D. Miles
Dept. of Civil Engineering
Purdue University
Lafayette, IN 47907

Dr. Jerry J. Nisbet
Institute for Environmental Studies
Ball State University
Muncie, IN 47306

Dr. John B. Patton
State Geologist
Indiana Geological Survey
611 North Walnut Grove
Bloomington, IN 47901

Dr. Howard Youse
P. O. Box 253
Greencastle, IN 46135

Appendix C

MEMBERS OF THE AD HOC PANEL TO PREPARE THE ANNUAL REPORT

Dr. John J. Corrigan
Associate Dean
College of Arts and Sciences
Indiana State University
Terre Haute, IN 47809

Dr. John Patton
State Geologist
Geological Survey
Indiana Department of Natural Resources
611 North Walnut Grove
Bloomington, IN 47401

Dr. Robert Henderson
Director
Indianapolis Center for Advanced Research
1219 West Michigan
Indianapolis, IN 46202

Dr. Phillip Powers
Director
Energy Engineering Center
Energy Administration
Purdue University
West Lafayette, IN 47907

Dr. Ralph A. Llewellyn (Chm.)
Chairman
Department of Physics
Indiana State University
Terre Haute, IN 47809

Appendix D

INDIANA NATURAL GAS: ACCOMMODATION TO REALITY

A Report to the Lt. Governor's Science Advisory Committee

TASK FORCE MEMBERS

MR. DUANE AMUNDSON
Vice President
Indiana Gas Corporation

MR. WILLIAM BEEMAN
Executive Vice President
Indiana Coal Association

DR. WILLIAM BERANEK
Holcomb Institute
Butler University

MR. ROBERT BERLIN
Indiana Energy Office
State Office Building

MR. BURT CALKINS
Manager
Operations Research Division
Applied Sciences Department
Naval Weapons Support Center

DR. DONALD T. CARR
Geological Survey
Indiana Department of Natural Resources

DR. JAMES COUGHLIN
Public Service Indiana

MR. ROBERT CRAVENS
(Executive Secretary)
Linton, Indiana

MR. DAVID DAVIS
Executive Secretary
Indiana Petroleum Council

DR. ROBERT HENDERSON
Director
Indianapolis Center for Advanced Research

MR. HAROLD HUTCHISON
Geological Survey
Indiana Department of Natural Resources

DR. FRANK INCROPERA
School of Mechanical Engineering
Purdue University

MR. STANLEY KELLER
Geological Survey
Indiana Department of Natural Resources

DR. CHARLES KILLPACK
Holcomb Institute
Butler University

DR. JAMES KOHN
Department of Chemical Engineering
Notre Dame University

DR. NORMAN LAURENDEAU
School of Mechanical Engineering
Purdue University

DR. DONALD LEVANDOWSKI
School of Geoscience
Purdue University

DR. RALPH LLEWELLYN (Chm.)
Chairman
Department of Physics
Indiana State University

MR. ROBERT LONGARDNER
President
Longardner and Associates

DR. KRAEMER LUKS
Department of Chemical Engineering
Notre Dame University

DR. STUART MCCOMAS
Department of Chemical Engineering
Notre Dame University

DR. BRUCE MCKENZIE
Department of Agricultural Engineering
Purdue University

DR. JAMES PATTERSON
Business Administration
Pennsylvania State University

Appendix D—Continued

DR. JOHN PATTON
State Geologist
Geological Survey
Indiana Department of Natural Resources

DR. ROBERT PEART
Department of Agricultural Engineering
Purdue University

DR. PHIL POWERS, Director
Energy Engineering Center
Energy Administration
Purdue University

MR. WILLIAM ROE
Chief Metallurgist
Bethlehem Steel Corporation

MR. WENDALL TAHLER
Indiana Gas Corporation

PRESIDENTIAL ADDRESS

CHEMISTRY, SCIENCE, AND CULTURE

Donald J. Cook, DePauw University

I wish to address you this evening on the broad subject CHEMISTRY—SCIENCE—AND CULTURE.

When I use the term WESTERN CULTURE each of you here has an instinctive understanding of what I mean; for most of you are scientists, and we are all heirs to the same great tradition of Western Culture. In specific language, we understand well the dictionary's sociological definition that "Culture is the sum total of a way of living—built up by a group of human beings—which is transmitted from one generation to another."

Another, and more specific meaning, defines culture as "The *training* and *refinement* of *mind, tastes,* and *manners*." It implies a *quality* of living—a constantly *improving* and *growing* way of living—through *learning*. And—most importantly—it also implies that Western Culture can continue as a stable culture *only* if its members are of a certain intellectual attainment; and—further—if the benefits of this, our culture, are to be transmitted to future generations there must be a greater appreciation of a *broad spectrum* of comprehension of all knowledge.

But is knowledge (in Latin known as *Scientia*) the *only* ingredient of our present culture? Are the *best* and *wisest* decisions for solving our many social problems always those which derive from the scientifically elite group of experts? During the time period from the end of the Second World War and into the mid-sixties science attained a high peak of influence. Society benefited greatly from the many new consumer products which resulted from wartime research. Television, the jet airplane, the computer, and even the conquest of space became a real part of our culture. Scientists in government, management, and academic life made vital decisions which non-scientists could not deter because science was king. This scientific influence even spread to the humanities and religion and attempts were made to make them "appear more scientific".

But in the short span of ten years we have become abruptly aware that in the total culture of a society there is no knowledge that is in itself king. In fact, we know that the ingredients of a true culture are not merely the "scientia" of the sciences (either physical or social); but that they also include our religious faith, our philosophy, our arts, and our humanities. For beyond all of knowledge there exists an even greater quality if we are to hope for an enduring culture. This quality has always been recognized by mankind. Robert Sinsheimer, Chairman of the Biology Division of Cal Tech, in a talk last June reaffirmed that quality which scientists must seek. He said in part, "We begin to see that truth is not enough—that truth is necessary but not sufficient—that scientific inquiry—the revealer of truth—needs to be coupled with wisdom if our object is to advance the human condition."

We cannot dismiss the acquisition of new knowledge or by law provide for a moratorium on all new research. We trust that the continued discovery of nature's laws will provide us with new technologies which can offer a higher cultural potential to all human beings. Although wisdom is not mere knowledge, wisdom as it is needed in our modern world is not possible *without* knowledge. Wisdom cannot be attained by meditation alone, and unlike other disciplines, wisdom is not a subject which can be taught as a part of our educational system. Wisdom in man is not infallible in the individual. The best source of wisdom derives from individuals who are possessors of great breadth of knowledge regarding the various components of a problem which exists or which is expected to exist at some future date.

If a society can become knowledgeable, in some degree, of the various facets of science, politics, economics, and sociology which are inevitably entwined—then possibly that society can find among its members those individuals who can pool their best wisdom in solving our problems. I firmly believe that scientists have a responsibility to speak of the role of science in our culture. Tonight I wish to speak as a chemist on the role which I believe chemistry has played in the shaping of our present culture. I am sure that each of you could also illustrate how physics, biology, engineering, geology, or any of our scientific disciplines have added their own unique contribution to our developing culture. And so I will speak of a few of the historical landmarks of chemistry.

It is believed that the practical knowledge that would eventually give birth to alchemy first originated in the predynastic period of Egypt (before 3400 B.C.). It is known that the early Egyptians worked with gold and silver. Their ability to produce glass on a large scale was well established by 1400 B.C. Some Chinese literature indicates that as early as the Third Century B.C. ideas characteristic of the beginnings of early alchemy were being employed there as well. But in Ancient Egypt, out of the land of Khem, came the knowledge Arabs would later identify as alchemy. Most of the discoveries in metallurgy, as well as those which lent themselves to the making of various kinds of materials, were obtained by chance. Those noble metals, gold and silver, which were found in the native state, were highly prized by the ancients because they could be worked so easily. The gold mines of Nubia were mined extensively by the Egyptians. One historian, writing in 1890, estimated that the gold mined in just one year in the Nubians would be valued at 125,000,000 pounds sterling, or approximately a billion dollars a year. The accidental discovery of glass in Egypt has been suggested as the result of adding soda to sand which acted as a flux in melting the sands which contained traces of gold. This early striving for gold would continue on into the Alchemical Period and lend its impetus to the search for the Philosopher's Stone.

The Greeks and Romans inherited the knowledge of matter which had originated in the Egyptian civilization. They improved upon these ancient metallurgical processes and developed new products. Bronze, which was probably first produced about 2500 B.C., was probably made from copper and tin oxide ore even before free tin was identified. This early knowledge of matter was of an empirical nature. There were no planned experiments such as are designed today and which are the heart of modern scientific study. It is difficult to understand why the gifted Greeks, who had made so many advances in mathematics and philosophy, did not organize into groups the many careful observations which had been made over the previous centuries and develop theories from these facts. Their disdain for physical work, and their fixed belief that the methods of thought and discourse were the only methods suited to study nature resulted in a philosophy—but not a science.

Even though Democritus proposed an atomic theory as early as the Fifth Century B.C., in which he imagined that all matter was composed of different types of atoms according to the nature of the substance, he had no other scientific bases for its acceptance but that it was a philosophical idea. It was not the result of experimentation. The concept of atoms as a valid scientific theory would not be introduced until the early Nineteenth Century by the chemist John Dalton. One might well pause to reflect that if the methods of philosophy and the dogmas of the many mystery religions (including the Christian faith) had continued as the dominant voices in man's intellectual development, it would have been impossible for modern Western Culture to develop as we know it. The use of an inductive method by a later generation of scientists produced the natural sciences and changed the direction of our culture.

As the Greek and then the Roman influence declined politically, and the devastation of barbarian conquest spread throughout Europe, a group of individuals centered around Alexandria managed somehow to preserve some of the ancient knowledge of matter. It is believed that in some of the writings of these Alexandrians (dating from the Third to the Seventh Century, A.D.) there is evidence of the first beginnings of alchemy. When the Moslems conquered Egypt in the Seventh Century and destroyed the priceless treasures of the great library at Alexandria, few could foresee that these people would be the successors to the learned Greeks.

But alchemy did become the province of the Arabs, and they continued the study of matter and its properties. The erroneous doctrine of transmutation of base metals to gold became entrenched in their thinking. Even so they left behind many valuable descriptions of chemical processes and introduced new methods of separation and the purification of various substances. But why—over the entire Alchemical Period—did no one recognize that the transformation of different substances into new ones was related to an ancient atomic theory? It is hard for us, who have been trained in the inductive methods of science, to understand that at one time the practicing alchemist had the ingrained belief that a substance would be transformed into a new substance only with the complete annihilation of the old substance.

But as the Sixteenth Century approached, alchemy was in the decline. The long-sought-after Philosopher's Stone would become more a matter of faith. Charlatans, in an attempt to maintain their favor in the courts of Europe, claimed that they had Divine assistance in their work. But many among the intellectual class began to distrust the alchemists. In the 1600's an event happened which would change the character of alchemy to that of chemistry. The introduction of printing made possible the dissemination of studies which would now be subject to broader criticism. A new spirit of freedom began to develop and emerge with the geographical discoveries of the New World and the exploration and colonization of these lands. As the century moved on scientific societies were organized in Europe and science began to achieve academic acceptance.

But—most important—some men were beginning to investigate the mysteries of nature, and they possessed new ideas as to how this should be done. Robert Boyle, born in 1626, settled in Oxford in 1654 where he carried on his studies until 1688, when he moved to London. He became the first President of The Royal Society in 1680 and guided its activities until his death in 1691. Boyle turned his thoughts to the concept of the atom of the element. He discarded the old Aristotelian idea of four elements and maintained that these "Certain primitive and simple or perfectly unmingled bodies; which not being made of any other bodies or of one another, are the ingredients of which all those so-called perfectly mixed bodies are immediately compounded."

But even as this new scientific spirit, based upon an inductive method, began to appear, there was also being proclaimed a concept of combustion which became widely accepted by most scientists—but which was entirely incorrect. The burning of matter—combustion—had been the focus of study for many years when Johann Becher set forth his view in 1669 that whenever a substance burned or was calcined, the combustible constituents of that substance—the terra pinguis-escaped. It was the escape of this material which gave the evidences of burning. Later, George Stahl built his similar idea of phlogiston. Each combustible material, including the metals, contained a substance—phlogiston—which escaped when the substance burned away; or, as in the case of a metal, became calcined to a powder. Since coal would burn until almost nothing remained, it was almost pure phlogiston. If a metal was heated, it too lost phlogiston, until its calx alone remained. To prove this had happened, if the metal calx was heated with coal, the phlogiston would again enter the calx and the metal would again reappear. He assumed that sulfur consisted of sulfuric acid and phlogiston, for upon burning sulfur, the phlogiston escaped and sulfuric acid was left.

Why he, or chemists who followed after him, would not question the difference in odor of the phlogiston from carbon as compared to the phlogiston from sulfur; or the fact that the calx of iron, which had lost phlogiston, now weighed more than the original iron, illustrates the hold a theory can have on the minds of knowledgeable individuals even though the theory is erroneous. Chemists such as Joseph Black, Carl Sheele, Henry Cavendish, and Joseph Priestley were phlogistonists in the full sense of the word. This doctrine, which did not completely disappear until the early 1800's, did have the positive effect of proposing an interpretation of many different observations from one common point of view. It was a beginning in the use of theory in the inductive method of reasoning.

It is natural now to turn briefly to Joseph Priestly, and to relate his contribution to the chemical and cultural development of our society. Priestley was born in 1733 in Yorkshire, near Leeds, England. His early training and study was in theology, and he became a Unitarian minister—a dissenter from the established Church of England. He was a free-thinker and prone to oppose his own government in the conflict between England and her American Colonies, and he sympathized with the Revolutionaries during the French Revolution. He was a friend of Benjamin Franklin; and he would heed his advice and that of his intellectual friends who lived in the community of Birmingham and the Severn Valley to embark upon scientific studies. His interests were broad, his natural instincts were to learn all he could about anything and everything.

In 1767, in Leeds, where he lived next door to a brewery, he found a ready source of 'fixed air', and began his studies which would culminate in his publication in 1772 on "Directions for Impregnating Water with Fixed Air." Dr. Joseph Black had obtained "fixed air" from heating limestone in 1754, and Henry Cavendish had produced "inflammable air" in 1766. These gases, it was believed at the time, were mere modifications of ordinary air. There was an excitement in Priestley to learn all he could about these "modifications". He designed a "pneumatic trough" to collect various gases; and he synthesized and collected sulfur dioxide, ammonia, and hydrogen chloride.

Possibly he decided to begin a study of heating various solids to find if they contained a gas, since Black had demonstrated the possibility of obtaining fixed air by heating limestone. It is to be remembered (although few historians record the date) that a memorable occasion in the history of civilization occurred on August 1, 1774, in Wiltshire, England, when Priestley focused his twelve-inch burning lens on a sample of red calx of mercury confined in one of his pneumatic tubes and produced his first sample of "dephlogisticated air". He had discovered, as he reasoned, a new modification of air which he found could support combustion much better than ordinary air and which must therefore contain no contamination of phlogiston since it could accept a much greater quantity of this element of fire more readily. Later in that year, he would visit Antoine Lavoisier in Paris and advise Lavoisier of his work. He subsequently published this study in March, 1775. These were all links in the chain when Lavoisier would report in 1777 on his theory of combustion and the identification of Priestley's gas (which was indeed the life-saving oxygen) as a component of air.

Priestley's outspoken sympathy for the colonists during our Revolution and his support of the French Revolution in 1791 led to the destruction of his home and laboratory in Birmingham by a mob. In 1794 he came to Northumberland, Pennsylvania where he lived out the remainder of his days. He died in 1804 shortly after his 70th year. The famous Priestley Award of the American Chemical Society recognizes Priestley the man and his distinguished work.

Priestley's contemporary in France, Antoine Lavoisier, was ten years younger. From an early age his career was that of a scientist, and he was soon recognized by the French Academy of Science. His work encompassed not only the discovery of new scientific information; but he also served France on many Boards and Commissions solving problems of administration on taxation, banking, scientific agriculture, and many other areas. His chemical research was directed to the quantitative study of reactions and it was not the common type of research prevalent in his day. It was his ability to measure and to weigh reactants and products of reactions which made it possible for him to bring order to the uncertainty which existed in the study of combustion.

In addition to his own detailed experimental work, he took the results of other's work, and wove their findings into a new chemistry. He helped organize a new nomenclature, and he wrote a new textbook on "Elements of Chemistry" which provided a systematic approach to the study of chemistry. His early recognition of oxygen as a constituent of many acids resulted in one forgivable error—when he forgot his own principle "Never to advance but from what is known to what is unknown", by his mistaken insistence that all acids contained oxygen. Lavoisier initiated a revolution in chemistry—but would himself become a victim of another Revolution. In May of 1794, the year Priestley came to America, Antoine Lavoisier was sent to the guillotine. Many would whisper "Only a moment to cut off that head and a hundred years may not give us another like it." Lavoisier well deserves his title of "The Father of Modern Chemistry".

Today we encounter the general belief of many that the influence of chemistry on our culture is the influence which chemical technology provides through the many beneficial, and sometimes not so beneficial, products it provides. But the intellectual contributions of chemistry are not recognized in many cases. The organization of new methods to solve the mysteries of nature—the incitement of a new spirit of intellectual inquiry were a vital part of the same spirit of freedom which burst upon the Western World in the late Eighteenth Century. This new cultural spirit was evidenced in the changes in religion, politics, literature, and the new science which Priestley, Lavoisier, and others helped bring about.

We might briefly retrace our steps and review one great technical development which was occurring at the same time as the sweeping changes in chemistry took place. In 1709, in the small village of Coalbrookdale, Shropshire, England, Abraham Darby I purchased an old iron forge and began to produce cast iron for the making of pots and kettles. In this year he found that in place of the widely used charcoal to reduce the iron ore, he could use—as a replacement for charcoal—coal which had been coked. Others had attempted to use coal for this purpose, but had been unsuccessful. It was Darby's use of sulfur-free coal to make his coke which made the reduction of iron ore possible.

Here was a potentially great industry which had been limited in its capability to produce iron by the lack of sufficient wood to produce charcoal, for the great forests of England and Europe had been dwindling away. Now this bottleneck had been overcome, and the way was open for the production of unlimited quantities of iron. And so in this year of 1709 the great Industrial Revolution was born in a tiny town in England and would spread throughout the world. By 1760 it would greatly influence our cultural direction. In this rural region of England—in the beautiful Severn Gorge—iron forges produced the iron to manufacture steam engines, iron rails and (yes) the cast iron stoves and cooking utensils which revolutionized the housewife's kitchen. The Darby Plant continued to grow—and in 1775 earned lasting claim to fame by building of cast iron the first iron bridge in the world. Completed in 1779, the ribs and beams, which had been cast at Coalbrookdale, were set to span the Severn Gorge, a distance of 120 feet. This structure, the ancestor of our massive bridges of today, still stands across the gorge at what is now known as the town of Ironbridge, England; and a great outdoor industrial museum is developing at this historic site.

This region of the Severn Valley and its outer-lying area was to breed an unusual quality of men. Josiah Wedgewood, the potter who raised his craft to a fine art and who was also a scientist in his own field, became—together with Erasmus Darwin—the grandfather of the great scientist Charles Darwin. They, along with Darby, Matthew Boulten, James Watt, and John Wilkinson, with his brother-in-law Joseph Priestley, were all members of the famous intellectual Lunar Society which had its meeting place in Birmingham and met at the time of the full moon—the better to travel. Their lives, their work, and their intellectual activities opened a new and wonderful door to our present cultural heritage.

One could continue to enumerate the work of chemists such as Dalton, Gay-Lussac, Berzelius, Wöhler, Liebig, Pasteur, and a great many others who lived in the Nineteenth Century; but we must limit our selection since so many of the discoveries of this generation of men were so significant. But I wish to pause briefly to consider some chemical technical developments. At the meeting of The British Association for the Advancement of Science in 1898, Sir William Crooks, in his presidential address, gave emphatic utterance in a warning of the world's future food problems. He stated that there was not enough fixed nitrogen available in the nitrate beds of Chile to supply the nitrogen nutrient for the growth of wheat and other grains to supply the world's needs in the near future. His disquieting message of approaching nitrogen starvation did not cause much worry among the world's politicians; but men of science understood well the danger to the human race. The control of the seas determined what nations would maintain a lifeline to the great Chilean deposits. In the early 1900's Britain, the United States, and France held that control. The Central Powers of Europe, under the leadership of Germany, were unable to undertake any massive military venture since their lack of nitrate kept them from producing the quantities of TNT and nitrocellulose necessary to conduct a long war.

Then in 1912 Professor H. A. Bernthesen announced at the New York meeting of the International Congress of Applied Chemistry that Fritz Haber and his associates in the Badische Anilin and Soda-Fabric located at Oppau, Germany, had at last discovered the method of converting nitrogen and hydrogen to ammonia. Since ammonia can be oxidized in the presence of platinum gauze to nitric oxide, it became possible to synthesize the needed oxide necessary to produce nitric acid. This freedom from the sea blockade of the importation of sodium nitrate from Chile guaranteed Germany a continued production of explosives; and in a brief two years the volatile political situation in Europe erupted into the destructive First World War. The long-sought-for chemical discovery to fertilize the fields of the world with fixed nitrogen did not result in an immediate blessing to mankind—but instead made possible World War I—which in another twenty-five years was followed by World War II. Today, with the blessings of lessened world tension, we are enjoying the benefits of fixed ammonia as we produce bountiful harvests of grain to feed the world.

We simply cannot evade or escape science and technology. The Haber process could not have been withheld from society because it also held within it the potential for devastating war. It was not necessarily the year of 1914 that brought forth the first paradox of the good and the evil in technology. The iron that armed the ancient Greeks came from the same process that ultimately produced the Industrial Revolution and the great modern steel industry. As we know, the potential for both good and evil becomes even greater with each new scientific advance—while, sadly enough, the paradox remains unanswered and unsolved.

Just as we can point to the positive intellectual impact which the study of pure chemistry has had upon the deepest roots of our culture; so too we also recognize that the less fundamental (but more dangerous) technical application of these intellectual discoveries have introduced a sometimes fearful but inescapable impact upon our daily culture. One cannot breathe, nor eat, nor live one's daily life without coming in contact with the potential dangers of modern technology.

Lastly, we should end this historical review of chemistry and science in our culture by joining chemistry with its sister science physics for a brief review of today's most miraculous technical advances. Who in 1780 would have suggested to Luigi Galvani and Allessandro Volta that their discoveries in current electricity would endanger the culture of the Western World? Would one want the work of Faraday stricken from the understanding of the chemical compound? Was Crooks' work in the cathode ray to be classified by a paternal government because it might become dangerous knowledge? And should Röentgen and Becquerel and Marie Curie not have recognized their accidental discoveries as a starting point in our understanding of X-rays and radioactive disintegrations? When Thompson and Chadwick identified the electron, the proton, and the neutron; could society or even the knowledgeable scientists of that day recognize that "When the sun sets, shadows that showed at noon but small, appear most long and terrible"? The shadows had appeared most long and terrible indeed when in August, 1939 Albert Einstein, with the prodding of physicist Leo Szilard, wrote to President Franklin D. Roosevelt;

> Sir: Some recent work by E. Fermi and L. Szilard, which has been communicated to me in manuscript, leads me to expect that the element uranium may be turned into a new and important source of energy in the near future. Certain aspects of the situation seem to call for watchfulness, and, if necessary, quick action on the part of the Administration.

We all know the results of 'quick action' by President Roosevelt and his Administration during the war years. And so the atomic age was not only born—but was in fact thrust upon us during the travail of a great global war. It came at a faster pace than if the world had been at peace—but perhaps no sooner than was necessary to counteract the then unforeseeable demands on our energy supplies which was to develop within the next thirty-five years.

And now we are concerned with another completely different chemical development with the elucidation of DNA by James Watson and Francis Crick. The potential of this purely scientific excursion into the realm of understanding life itself has been likened to the potential of nuclear energy. We cannot discard the fact that knowledge is power—and power is always dangerous. But any culture which continues to grow through the intellectual ability and creative talent of its philosophers, its theologians, its artists, its writers, and its scientists will always have to exist within the blessings and the dangers which the technologies derived from the intellect will always produce.

As an Academy of Science, with a membership of persons who are more knowledgeable of the good and of the bad which science—through its technology—brings to society, we must accept our responsibility to advise and to educate those possessing a lesser understanding of science. We must also be prepared to work with those who make the decisions for the uses of science so that, to our best ability, the gift of wisdom will continue to bring the blessings of science into our culture.

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ANTHROPOLOGY

Chairman: Benjamin K. Swartz, Jr., Department of Anthropology
Ball State University, Muncie, IN 47306

Chairman-Elect: Edward M. Dolan
DePauw University, Greencastle, IN 46135

ABSTRACTS

Preliminary Comments on an Historic Miami Site in the Mississinewa River Valley. Russell E. Lewis, Department of Sociology, University of Evansville, Evansville, Indiana 47702.——During the summer of 1976, Ball State University conducted excavations in Wabash County, Indiana in an attempt to locate the site of the Battle of Mississinewa (December 17 and 18, 1812) and associated Miami village sites.

Excavations were concentrated in an area thought to be the former village site of Miami leaders Metosinia and his son Meshingomesia. Dr. B.K. Swartz, Jr., B.S.U., was project director; Dr. Elizabeth Glenn, B.S.U., served as the project ethnohistorian; and, the author served as field director for the excavations and is responsible for the analysis of the fieldwork and artifact assemblage.

Archaeological and archival data indicated the presence of a cabin which could have been occupied from circa 1813 to 1874. The dimensions of the cabin were approximately 10 feet wide by 20 feet long with end posts spaced 4 feet apart and side posts spaced 5 feet apart. The cabin had a fieldstone foundation, dirt floor, a door on each of the long sides, and a pit hearth 15 inches in diameter. Window glass was also present in the cabin floor area. Archival data indicates that such cabins were being constructed on the Miami Reserve at least as early as 1827.

The artifact assemblage has been compared with the artifact assemblages of sites from roughly the same time period, including sites located in California, Georgia, Illinois, Kansas, Michigan, Minnesota, New York, and Ontario. The assemblage includes most of the items which one would expect to find in a Late Historic (1780-1820) through Civil War era Indian village site. Most of the artifacts were trade items of European manufacture. Some American materials and a limited amount of native Miami materials were also recovered.[1]

Included in the artifact assemblage are the following: a variety of glass and shell trade beads; Dutch, French and English gunflints; gun parts, musket balls, and percussion caps; trade silver including brooches and a tinkling cone; forged and cut nails; iron, brass, copper, lead, and pewter artifacts consisting of kettle and knife fragments, tinkling cones, bells, Jew's harps, etc.; worked bone and antler; glass and ceramic fragments; shell, bone, metal, porcelain, and glass buttons; and English and American kaolin pipe fragments.

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[1] In addition to the artifactual material discussed here, there were also 420 non-human bone and tooth fragments recovered. E. Joseph Fabyan, B.S.U. Graduate Student in Anthropology was responsible for the faunal analysis.

The majority of the material indicates that the cabin was probably occupied circa 1830 to 1870, although there is a limited amount of earlier material in the assemblage. For more information and a preliminary site report contact the author.

The Chert Assemblage of the Daugherty-Monroe Site, A Circa 400 A.D. Village. GARY A. APFELSTADT, Department of Anthropology, University of Illinois-Urbana, Urbana, Illinois 61801.——Excavations have been conducted at 12-Su-13 for several years to mitigate the impact of proposed levee construction. This report summarized the analysis of the chert remains that were recovered during the 1975 season. Based upon earlier studies, this analysis employed an imposed categorization. It was conducted without microscopic wear-damage analysis, and it was undertaken to determine the patterns of chert utilization and on-site activity. The items are attributed to tool use, flint knapping, firing activity, or unidentified. The artifacts with characteristic firing attributes result from at least two sets of heating conditions. Behavioral correlates of these may be stone boiling, stone hearth, and heat treatment methods of use and preparation. The waste from flint knapping activity was segregated among four categories (i.e., cores, decortication flakes, preparation flakes, bifacial flakes) with the latter three representing successive units of lithic reduction. The chert tool categories include stemmed bifaces, stemless bifaces, core unifaces, flake unifaces, and blades; they were tentatively grouped into cutting, scraping, perforating, or projectile type functions. From the observation of material type, it is evident that the inhabitants practiced differential use of materials. Non-local materials predominate in the categories of blades, stemmed bifaces, and bifacial flakes, while local materials account for all of the stemless bifaces, unifacial flake and core tools, and for most of the cores, preparation flakes, and decortication flakes. On this basis, it is likely that: a) chert was a multi-purpose resource; b) local materials were used in the range of activities; c) non-local materials were used in a restricted set of activities; d) local materials were transported to the site before reduction to tool forms; e) non-local materials were transported to the site after reduction to tool forms; and, f) tools of both materials were reworked at the site.

A History of East-Central Indiana Archaeological Study. B. K. SWARTZ, JR., Department of Anthropology, Ball State University, Muncie, Indiana 47306.——Four periods of scholarly prehistoric study in East-Central Indiana are identified and described: (1) Pioneer Speculative Period (1800-1847), (2) Pioneer Descriptive Period (1847-1937), (3) Professional Excavation Period (1930-1964), and (4) Professional Classificatory Period (1964-).

An Incised Mortuary Head Rest Stone from Madison County, Indiana.

B. K. SWARTZ, JR.
Department of Anthropology, Ball State University
Muncie, Indiana 47306

In response to a call received by the Department of Anthropology, Ball State University, on October 24, 1975, a team of archaeology graduate students was dispatched to the Gillespie farm, eight miles north of Chesterfield, Madison County, Indiana, to record the exposure of a disturbed human skeleton. The site of this recovery was designated M-65 (IAS-BSU). When the bones (many relocated by local resident youths) were collected the cranium was removed, revealing *in situ* a stone with inscribed lines (Figures 1 and 2) directly below. The idea of a mortuary head rest recurs in this area. There is a questionable report of a head rest stone from Delaware County (D1-2? IAS-BSU) about 1889 by "Bunt" Swearington. "The head resting on a piece of material about the size of a saucer" (3). At the Middle Woodland New Castle site, Henry County, Indiana, a skull may have been placed on a sheet of untrimmed mica (4, p. 5).

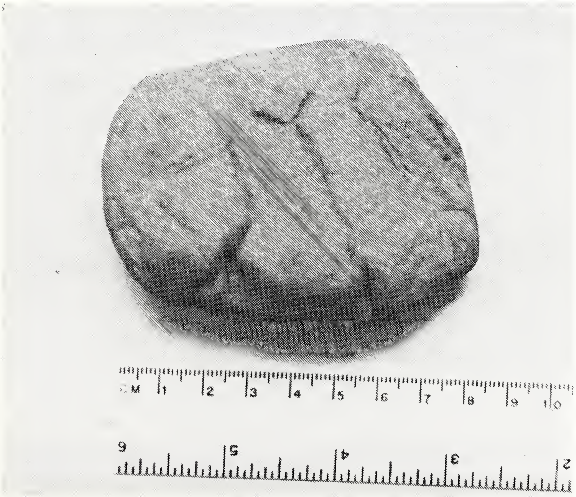

FIGURE 1.

It should be noted that lineal depressions on soft stone surfaces can easily be formed by natural processes such as differential weathering of alterations made by root growth, water erosion, soil movement, etc. Though the find is on the glacial Tipton till plain the marks are not glacial striations, nor are they made from earth altering devices such as plows. To the writer the rock is unusual. It could be a manuport (i.e. also unusual to a prehistoric observer, hence suitable as an offering to the dead). Though no specific tool markings are detectable, due to the soft rock surface, prehistoric inscribing seem likely.

The stone was oriented so that the incised design was against the cranium, with the lines radiating in a posterior direction. On June 8, 1976 Mr. LaVan Martineau, who was visiting the writer, examined the stone and interpreted the incised design on the basis of ideas expressed in (5). He termed the central line a "bird track" with a slight off-set at the point of bifurcation. Such a marking refers to a person of importance; inversion of the element to dying or death; the off-setting of the line to failure, i.e. *an important person who failed has died.* This idea is compatible with the archaeological context, though the author realizes that the relating of accounts from prehistoric pictography is a controversial activity.

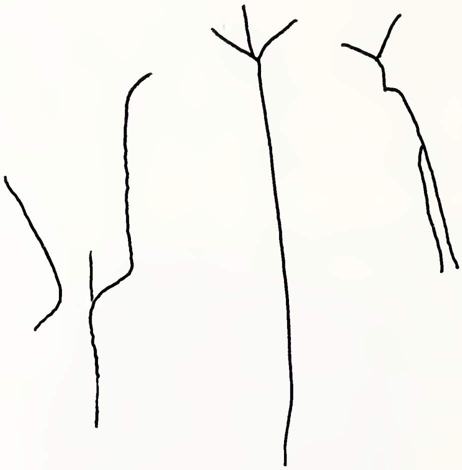

FIGURE 2.

The Madison County stone was composed of dense solidified silt. Due to the context of the discovery and the density of the stone it was thought that possibly the stone might have been aboriginally "manufactured" by coating a heavy rock with hardened silt. Radiography (Figure 3) disproved this idea.

No parietal rock markings, i.e. *petroglyphs*, have been professionally recorded from Indiana (2, pp. 17). There was a cave at Mounds State Park, Madison County (1) in which persistent local rumors of aboriginal habitational evidence (smoke blackened ceilings) and occasional mention of "wall markings" were recounted. Former rock markings representing three turtles, have been reported at Totem Rock or Salt Peter Cave, DuBois County (6).

The markings on the Gillespie stone, especially because of its context, can possibly be regarded as an example of *"inscription mobilier"* from Indiana.

Acknowledgements

The Ball State University graduate students who conducted the salvage operation were Raphael L. Schwartz, E. Joseph Fabyan and Daniel L. Plamann. Radiography (Figure 3) was done by Betty Allen, Ball Memorial Hospital.

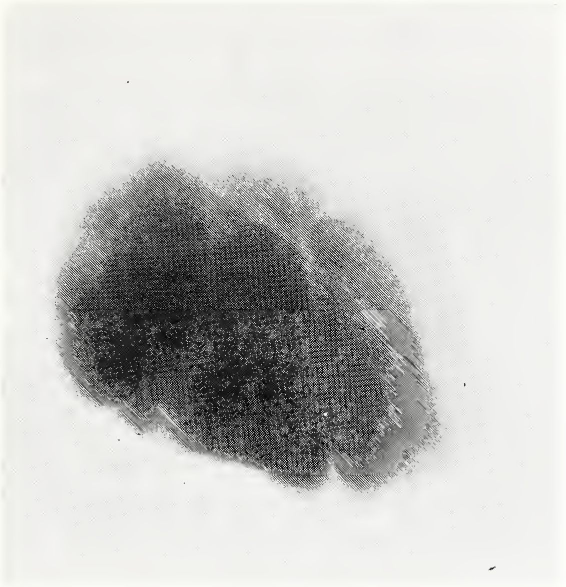

FIGURE 3.

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Field Forensic Anthropology: The Excavation of Human Remains under Adverse Conditions

CHARLES P. WARREN
Department of Anthropology
University of Illinois at Chicago Circle, Chicago, Illinois 60680

Abstract

Field Forensic Anthropology: The Excavation of Human Remains under Adverse Conditions. Charles P. Warren, Department of Anthropology, University of Illinois at Chicago Circle, Chicago, Illinois 60680. The recovery of war casualties from former combat zones was an activity routinely performed by U.S. Army search and recovery teams in Southeast Asia. This is an account of one such recovery and its associated hazards as reported by a physical anthropologist who accompanied the team during a recovery in Hue, Republic of Viet Nam.

Introduction

An awareness of the applicability of modern archaeological techniques in the search and recovery of contemporary human remains and as an aid in forensic investigations has been reported recently in the literature (3, 4). These prescribed techniques have an even wider function in the exhumation of the buried remains of battle casualties by military recovery teams.

Planning Military Recovery Procedures—An Example

Early in September, 1974, an American official working in Da Nang, Republic of Viet Nam, received information from local sources in Hue, Republic of Viet Nam, concerning the burial of two Americans in Hue City during Tet, 1968. Hue, the ancient capital of Viet Nam, lies on both sides of the Perfume River, 685 miles north of Saigon and 60 miles south of the 17th parallel, which, at the time of this report, was the line of demarcation between North Viet Nam and South Viet Nam.

Reportedly, fifteen Vienamese and two Americans were buried in a mass grave inside the walls of the citadel of Hue City. Further investigation of the report revealed that an eye-witness informant was available to point out the exact site and to give an account of the events of the burial. According to the informant, he, a resident of Hue City, returned to his house in the citadel a few days after the withdrawal of the Viet Cong troops, sometime in late February, 1968. He and his neighbors had received orders from the local authorities to help pick up all of the dead bodies which had been left lying around their living areas for burial along the walls of the citadel. The informant stated that he and some of his neighbors recovered the bodies of fifteen Vietnamese and two American soldiers, and all were then buried in a single bomb crater which was located behind the wall of the citadel on Nguyen Thanh Street. The informant further stated that the two American remains had been found at the intersection of Nguyen Thanh and Dinh Cong Trang Streets, about 100 meters from the gravesite. Both Americans reportedly had red hair and white skin. The tall one was described as wearing green jungle trousers and a tee shirt and had been wounded in the stomach; the smaller one was described as wearing a green jungle shirt and undershorts and had been wounded in the neck. According to the informant, no parts of the bodies were lost after they were wounded, and the informant did not remember having found anything in the pockets of the clothing or having seen any dogtags or nametags.

This information was passed on through channels, and subsequently plans were made to send a team of U.S. Army search and recovery personnel to the site. The personnel of the search and recovery team were all based in southeastern Thailand at the U.S. Army Central Identification Laboratory, and the mission required six military recovery specialists and one civilian physical anthropologist to conduct the proposed search and recovery operation in Hue City. Since there had been recent political unrest and demonstrations in Hue, and since the Viet Cong and North Vietnamese troops had infiltrated the area, the planners of the operation constantly stressed the importance of tight security throughout the entire operation. The local authorities agreed to provide the security forces, composed of police, and these police would be on site prior to the arrival of the Central Identification Laboratory personnel. A complete sweep of the area would be made, and the road next to the site would be blocked off and the traffic redirected. Police would be stationed around the area and at the site itself, and at least three policemen would be left at the site during the night to provide twenty-four-hour security. Each day there was to be another sweep of the area, a blocking of the road, and the posting of police prior to the beginning of any activity by the American personnel. Radio communications would also be established. This plan was acceptable to the American officials in charge of the planning, so the search and recovery mission was activated.

The members of the search and recovery team departed from their base in Thailand and, after plane flights to Saigon and then Da Nang and a helicopter flight to Hue, arrived at the base of operations in Hue City early in the morning of September 16, 1974. Soon after their arrival, the search and recovery team was briefed on the evacuation plan and what to do if there was an attack. The team members were also briefed on how to respond to the members of the press who would most likely be at the site. Because of the danger, the entire city of Hue was declared off-limits to the team personnel and the accompanying American officials, and all activities were thus confined to the hotel for billeting and meals, the base of operations, and the site of the proposed excavation.

The Recovery and Problems Encountered

The remainder of this report will be confined to the anthropological and archaeological aspects of the recovery of human remains in Hue, Republic of Viet Nam, on 16 and 17 September 1974. The site, at Grid Coordinates YD 765 229, inside the citadel of Hue City, was observed to be a mound of grass-covered earth lying between an all-weather road

(Nguyen Thanh Street) and a brick wall which paralleled the road. Similar mounds were apparent along the length of the wall. The excavation and attempted recovery of human remains began at 0915, with indigenous labor moving most of the clay and brick aggregate which was encountered as the digging proceeded. The workmen were instructed to dig two trenches, parallel to one another and flanking the mound. This kept the mound intact until a level three feet below the surface was reached. At this level the workmen were instructed to slowly remove the aggregate from the exposed surfaces of the mound and to gradually work downward, keeping the areas underfoot clear of dirt and rocks as the mound was dismantled. The first remains were uncovered at 1045; a left scapula and several rib fragments were thrown loose by the workmen. At this time the members of the team took over the exhumation; the procedure described above was continued, and several incomplete and fragmentary remains were recovered and bagged. At 1150 the work was stopped for a lunch break.

After a check by the recovery team for booby traps, the work was resumed at 1400, with the systematic excavation of the mound being periodically slowed by the recovery of remains. The indigenous laborers had to be restrained continually, for their prime interest was in digging and completing the job, whereas the recovery team wanted the remains as undamaged as possible. At least three incomplete individuals were recovered by 1515, but the burials had not been systematic, so commingling was inevitable. As could best be reconstructed from the meager evidence, the individuals had been collected and haphazardly tossed into the open grave. The unsystematic distribution of remains made it extremely difficult to ascertain the positioning of the individuals and to complete the subsequent diagramming of the contents of the site.

As the work progressed throughout the afternoon, several bones not associated with the recoveries were sifted from the dirt which had been removed from the top of the mound. These bones were of a different texture from the more deeply buried remains and may have been later intrusions. The results of the work of the afternoon could best be summarized as four commingled recoveries of incomplete and fragmentary remains found in odd positions, plus several bones which may have come from other sources. Work was discontinued at 1630.

The next morning at 0750 the area was again checked for booby traps and mines, and the workmen were then instructed to remove the remaining portions of the mound and to continue to excavate the entire floor of the site down about six inches more to the clay surface which marked the bottom of the pit. During this activity, the first grenade was uncovered at 0840, and it was disposed of by one of the team members, who threw it over the wall behind the gravesite. The second grenade was uncovered at 0850, and the task of ridding the site of this danger was assumed by enlisted personnel of the army of the Republic of Viet Nam. Both grenades were old ordnance and, as a consequence, were very dangerous for the excavators and spectators alike.

At 0915 two remains were uncovered which had heavy ropes tying the leg and ankle bones. This evidence suggested possible atrocities, and the apparent lack of clothing on or with all of the remains recovered further suggested that the individuals had been stripped and tied, then killed and buried. At 1135 the morning work ended.

The recovery team and the Vietnamese workmen returned to the site at 1400 and resumed the excavation after clearing the area. By this time a pit 4.5 X 3 X 2 meters had been dug, and the bottom of the pit was floored with a yellow clay which had not been penetrated by the original excavation. All remains were removed by 1450, and, after scraping the surface of the pit floor to verify the maximum depth of the original pit, the excavation was declared complete, and the workmen were instructed to refill the pit. This was partially completed by 1630, at which time the recovery team left the site and the remainder of the work to the indigenous workers. An inventory at this time totaled seven fragmentary and incomplete recoveries, extensively commingled, plus an assortment of tentatively nonassociable portions. All recoveries were packaged in bags and boxes marked to reflect the above findings.

Evaluation of Personnel Training and Procedures

This site was an extremely difficult site to excavate and exhume, due to the limitations set by time and the lack of precise information. Furthermore, the procedures for performing this type of task are not described in the field manuals which discuss the handling of human remains in military field situations (1, 2, 5). Consequently, military recovery teams are not trained for this type of recovery, and the success of this particular recovery was due primarily to the ingenuity and perseverance of the recovery team members as they surmounted an unfamiliar task. Obviously, the recovery team was pressed for time, since a similar enterprise under strict archaeological conditions would have occupied at least a week of slow, painstaking excavation.

At this point it might be of interest to discuss the conditions of the soil at the site. These remains were reportedly buried in February, 1968, thus giving a burial span of about five to six years. As previously stressed, the remains were incomplete and fragmentary, and this sparseness of the remains was due to the actual disappearance of the bones as a result of dissolution and absorption by the surrounding soils of high acidity. Given additional time, no bones, and only some of the teeth, would have been found. The recovered remains consisted mainly of skulls and teeth, shafts of the long bones of the arms and legs, fragments of pelvi, and minor scraps of vertebral columns. Hand and foot bones had largely disappeared, as had the proximal and distal ends of the long bones. Under other conditions of burial, e.g., dry, sandy alkaline loam, complete, undissolved skeletons may have been present for recovery.

Bioanthropological and Bioarchaeological Recommendations

As a result of the experiences and insights gained during the two days of work at the site in Hue City, Republic of Viet Nam, the following recommendations were offered:

a. *Provide more accurate detail as to the exact location of the site.* Better intelligence as to the location of the site of the remains being sought is imperative, since this type of recovery, in contrast to surface recoveries of aircrash sites, requires excavation of the alleged burial site to completion, even though doubts may arise as to the accuracy of the location of the site at any point in time during the excavation. It may be added that when the recovered remains were processed in the laboratory in Thailand, all of the individuals were Southeast Asian Mongoloids.

b. *Provide special training for search and recovery teams in the techniques of disinterment of commingled human remains.* In contrast to the removal of burials in temporary military cemeteries—techniques which are described in the appropriate field manuals (1, 2, 5)—this type of disinterment requires special tools and special techniques, and the uses of these special tools and techniques are given as part of the training at all archaeological field schools; such training should be part of the training of military search and recovery teams.

c. *Provide better security at the site.* The tedious task of carefully excavating human remains is difficult under the best of circumstances, but when the team workers are fully aware that they are in danger of ambush or attack, then the levels of concentration and attention to the task at hand are reduced correspondingly. Fortunately, no incidents occurred at this particlular site, but this good fortune cannot be attributed to the quality of the security provided at the site.

d. *Provide special training for some members of the recovery team in the handling of ordnance uncovered as sites are being worked.* Mass burials after combat inevitably include inadvertent burials of explosives of a variety of types. Unless specialists from appropriate branches of service are on call during excavations of this type, all work must stop at the site whenever such ordnance is uncovered. The task of the recovery team is to recover remains, not produce them.

e. *Inform the appropriate authorities of the changes in buried bone through time.* Correct decisions as to whether sites should be excavated can best be made if there is a broader dissemination of technical and scientific information regarding the responses of human bone to varying soil conditions (6). There must be a full awareness on the part of the authorities that, under the proper conditions, bones originally buried in a site can disappear completely, and nothing other than the artifacts of the burial will be found at the site. In the recovery of human remains, this should be a normal expectation, and the disappointment at finding fragmentary portions or no remains can be eased by the realization that the result was due to natural causes—rather than the lack of capability of the excavators of the site.

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BOTANY

Chairman: Roger F. Boneham, Department of Geology
Indiana University-Kokomo, Kokomo, Indiana 46901

Chairman-Elect: Gary E. Dolph, Indiana University-Kokomo
Kokomo, Indiana 46901

ABSTRACTS

Origin and Development of Non-Articulated Laticifers in Leaves of *Catharanthus roseus*. Larry R. Yoder, Botany Department, The Ohio State University, Marion, Ohio 43302.——Sectioned leaves and whole mounts treated with Jeffrey reagent show a laticifer system that arises from initials that first appear when primordia are about 500 μm long. Additional initials differentiate behind the marginal meristem where they form a system of subdermal and vasculature-related laticifers oriented parallel with or at right angles to the longitudinal axis. Longitudinally-oriented laticifers were present just beneath the lower epidermis across the entire abaxial surface and in association with the phloem on the adaxial and abaxial sides of the bicollateral bundles in the petiole and midrib. Subdermal laticifers were present around the outer circumference of the petiole. Laticifers oriented at right angles to the midrib were associated with the xylem in minor veins. Earlier investigations failed to recognize laticifers associated with the minor veins and those along the margin and lower epidermis. Laticifers present beneath the epidermis of the blade and petiole are derived from ground tissue; those associated with the vasculature are presumably derived from the procambium. Occurrence of laticifers next to xylary elements in the minor veins is unique among laticifer systems that have been studied.

Stipulate Leaves from the Middle Eocene Claiborne Formation of Tennessee. John L. Roth and David L. Dilcher, Department of Plant Sciences, Indiana University, Bloomington, Indiana 47401.——Fossil leaves previously identified as *Leitneria eocenica, Diospyros wilcoxiana, Anacardites marshallensis, Schefflera? elliptica* and *Carapa eolignitica* were examined and found to have persistent adnate stipules. The stipules are unique to a single leaf type in the Eocene flora of Tennessee and exclude these leaves from the previously identified taxa. Cleared leaves from several modern genera and cuticular preparations for light microscopy and S.E.M. of both the fossil and modern material were used in comparing the fossil leaves with extant taxa. The gross morphology, venation and cuticular features of the fossil leaves appear to circumscribe a new leaf form. No extant taxon has been found with the same combination of features observed in the fossils.

Occurrence of Lycopod Fossils in The Path Fork Coal Zone of Harlan County, Kentucky. Larry R. Yoder, Botany Department, The Ohio State University, Marion, Ohio 43302.——Plant fossils were collected at a site adjacent to the Harlan Airport runway south of U.S. Rt. 119 in Harlan

County, Kentucky. Fossils exposed during runway construction occurred in soft shale, sandstone and clay of The Path Fork coal zone, Hance formation in the middle Pennsylvanian. Clay above the coal seam contained abundant *Pecopteris* and *Calamites*. Two negative stump casts of *Lepidodendron* 30 cm in diameter and a 3 m section of *Lepidodendron* trunk 35 cm in diameter were observed in the sandstone. One small cast of *Sigillaria* was also observed. Frequent examples of *Stigmaria ficoides* occur in the soft shale above the sandstone. Many roots lie parallel with the plane of the sandstone and are easily followed for several meters. A 7 m section with a uniform diameter of 8 cm was the longest root collected. Erosion had scattered the remaining parts of this specimen and no bifurcations were recovered. Rootlets ½-1 cm in diameter were intact where the specimen was still buried. Numerous fragments have been washed down at this location, and erosion in the soft shale will eventually destroy the continuity of remaining specimens.

The Accuracy of Paleoclimatic Estimates Based on Foliar Physiognomy. GARY E. DOLPH and DAVID L. DILCHER, Division of Natural and Physical Sciences, Indiana University at Kokomo, Kokomo 46901 and Department of Plant Sciences, Indiana University, Bloomington 47401.——Data collected from modern regional floras have been interpreted to indicate that leaf form and climate are correlated. Leaf margin type, as measured by the percentage of woody dicotyledons in a flora having leaves with entire margins, has been correlated with mean annual temperature; leaf size distribution, one estimate of which is the percentage of woody dicotyledons in a flora having large leaves (greater than 20.25 sq. cm. in area), with mean annual rainfall. Angiosperm paleobotanists have used these two correlations to estimate paleoclimate. To test the accuracy of paleoclimatic estimates, the mean annual temperature and mean annual rainfall patterns for North and South Carolina were estimated using leaf form. The estimates were compared with the patterns actually observed. Because the majority of data on modern leaf size distribution comes from the tropical life zones of the western hemisphere, insufficient data were available to estimate the mean annual rainfall of the Carolinas. Using the percentage of woody dicotyledons having entire-margined leaves in each county of North and South Carolina, the variation in mean annual temperature was estimated. The mean annual temperature on the coastal plain was estimated to be greater than 22° C with the mean temperature of the coldest month being between 15 to 18° C. For the remainder of the Carolinas, the mean annual temperature was estimated to range between 15 to 19° C with the mean temperature of the coldest month being between 6 to 10° C. These predictions overestimate the temperatures actually observed in the Carolinas. Therefore, paleoclimatic predictions based on broad regional correlations between leaf form in modern floras and climate can be inaccurate.

Botanical Data Banking. THEODORE J. CROVELLO, Biology Department, University of Notre Dame, Notre Dame, Indiana 46556.——Computerized data banking in botany today is experiencing rapid but uneven growth. Its history and current growth rate depend on the type of data being banked, the area of botany in question, and whether the data bank is to serve basic or applied research needs. Botanical information input to a data bank may consist of: a) literature citations or more complete descriptions of printed work; b) information from botanical specimens (living or dead); c) information about the environment in which the specimens are found; or d) information based on experiments performed in the laboratory or in more natural environments. Banking of botanical literature has had the longest history, and covers all areas of botanical study. However, data banking of information in botany other than literature has been most intensively undertaken in the areas of ecology and systematics. Sometimes this has occurred under the aegis of a large project (e.g., The International Biological Program), but data banks of single workers or of single institutions also are very common. Botanical data banking has progressed far enough, and uncontrolled enough such that compatibility of data banks and of networking are most timely topics.

Development of Non-Articulated Laticifers in Embryos of *Carissa grandiflora*. LARRY R. YODER, Botany Department, The Ohio State University, Marion, Ohio 43302.——Non-articulated laticifers arise at the outer margin of the procambium in the cotyledonary node and form an extensive system consisting of an estimated 18-30 branched cells in the mature embryo. These acuminately-tipped cells appear to grow intrusively and they contain one or more spindle-shaped nuclei with prominent nucleoli. Most branching and ramification occurs in the cotyledonary node where laticifers penetrate to the periphery of the cortex but not inwardly through the procambium. Laticifer growth away from the cotyledonary node generally follows the margin of the procambium. Those in the hypocotyl extend ⅔ of the distance to the root meristem and exhibit few branches in their distal portions. They do not penetrate the root meristem. Laticifers also extend into the cotyledons where they are associated with the procambial strands. *C. grandiflora* is considered a primitive member of the Apocynaceae, subfamily Plumerioideae, and the occurrence of branching laticifers associated with the procambium supports the hypothesis that branching represents a primitive condition in laticifer evolution within this family.

Macroscopic Variation in Fossil and Modern Oak Leaves. MARILYN K. GILBREATH and GARY E. DOLPH, Division of Natural and Physical Sciences, Indiana University at Kokomo, Kokomo 46901.——Thirty-nine lobed red oak leaves were collected from the Upper Miocene Sardine Formation in western Oregon. These fossil leaves were compared with leaves from 22 modern species of lobed red and white oaks. The fossil and modern oak leaves studied were very similar in gross morphology, except for differences in the shape of the lobes and the presence or absence of bristle tips. The oak leaves studied had the following gross morphological features in common. Lobules were present on the majority of leaves. The secondary venation was craspedodromous. The tertiary veins joined together in a series of prominent arches in each lobe except for an occasional tertiary vein which would terminate at the tip of a lobule. Below each sinus, a tertiary vein arising from the midrib branched and joined the arching tertiary veins in the lobes above and below the sinus. A fimbrial vein was present just inside the margin of each leaf. The higher order venation was random reticulate. The areolae were triangular to pentagonal in shape. Finally, the veinlets terminating in the areolae were branched. The similarity noted in the gross morphology of the fossil and modern oak leaves studied raises the question of the validity of the more than 150 species of fossil oaks that have been identified. Many species are undoubtedly synonomous with others. Identification of fossil oaks are particularly tenuous when more than one species occurs at the same locality.

Microscopic Variation in Fossil and Modern Oak Leaves. Beecher A. Waters and Gary E. Dolph, Division of Natural and Physical Sciences, Indiana University at Kokomo, Kokomo 46901.——Many investigators consider cuticular morphology as superior to gross morphology for identifying species. The species of fossil and modern oaks having lobed leaves are difficult to identify using venation characters. Therefore, an attempt was made to distinguish between 39 fossil lobed red oak leaves collected from the Upper Miocene Sardine Formation in western Oregon and 22 modern species of lobed red and white oaks using cuticular morphology. The leaves were compared using 206 cuticular characters. The leaves of *Quercus alba* could be distinguished from those of the other species by the presence of two-celled glandular hairs on the lower epidermis. No diagnostic differences were found between the remaining modern and fossil oak leaves, although environmentally induced differences in characters such as cuticular thickness (*Q. albocincta*), lower epidermal cell shape (*Q. Kelloggii* and *Q. nitescens*), and lower epidermal trichome density (*Q. oleoides*) were present. The modern and fossil oak leaves had the following cuticular characteristics in common. The leaf cuticle was thin and unornamented. The cells of the upper and lower epidermis were isodiametric with straight to undulate anticlinal walls. Unicellular, pointed trichomes appearing either singly or in tuffs were present on both leaf surfaces. The trichomes were more numerous on the lower epidermis. Anomocytic stomates with T-pieces of thickened cutin at the poles of the guard cells were confined to the lower epidermis. The cuticular morphology of the oak leaves studied was sufficiently constant to allow the genus to be identified with assurance. However, cuticular morphology does not offer a mechanism by which the majority of lobed oak species, either fossil or modern, can be identified.

Occurrence of Jeffrey Reagent, Neutral Red, IKI, Dragendorff's Reagent, and PAS Reactions in Stems and Leaves of *Carissa grandiflora*. Steven R. Shafer and Larry R. Yoder, Botany Department, The Ohio State University, Marion, Ohio 43302.——Freehand stem and leaf sections of *Carissa grandiflora* were treated with Jeffrey reagent, neutral red, IKI, Dragendorff's reagent and periodic acid-Schiff reagent. *Carissa*, unlike several other members of the Apocynaceae, is reported to contain no alkaloids. However, Jeffrey reagent, which has been used as an alkaloid indicator, reacted with certain cells in *Carissa grandiflora*. In stems, Jeffrey-reactive cells occurred beneath the epidermis, as linear series in the cortex, and as cortical isolates. Jeffrey-positive cells occurred in the palisade mesophyll, along the foliar midrib, and adjacent to the lower epidermis. Neutral red and the alkaloid indicators IKI and Dragendorff's reagent stained neither Jeffrey-positive cells nor the branched, non-articulated laticifers located near the vasculature of stems and leaves. The PAS test in the Jeffrey-positive cells revealed dense, granular material which is interpreted to be an insoluble polysaccharide other than starch. Jeffrey reagent can be used as an alkaloid indicator, but this study indicates that Jeffrey reactions must be interpreted cautiously because of possible false-positive reactions.

A Study as to Whether the Variability Illustrated by *Melilotus alba* and *Melilotus officinalis* Specimens is Due to Polymorphism or Speciation. WILLIAM J. DAYTON and BETTY D. ALLAMONG, Department of Biology, Ball State University, Muncie, Indiana 47306.——The major purposes of this study were to see whether or not *Melilotus alba* and *Melilotus officinalis* specimens in the area were, in fact, species specific and to illustrate the methods by which they have, or might have, been separated as competitor species. *Melilotus* plants were studied at area sites and in the laboratory. This study used a variety of techniques to illustrate characteristics of the two species. A comparison of the percentage of seeds that are viable with the percentage of seeds that germinate was completed. The rate of plant growth was illustrated, as were the roles of light and temperature stimuli. Chromatography and electrophoresis were used for comparative analyses of plant biochemistry. In this study, the chronology of maturation and the sites where the *Melilotus* species were located were postulated to be major factors in the processes of speciation. These time and space properties were associated with the rare reports of spontaneous hybrids.

Some Effects of Cadmium on Water Relations of Silver Maple Seedlings. ROBERT J. LAMOREAUX and WILLIAM R. CHANEY, Department Forestry and Natural Resources, Purdue University, West Lafayette, Indiana 47907.——Effect of $CdCl_2$ on water movement in stems of eight-week-old silver maple (*Acer saccharinum* L.) seedlings grown in sand amended with 0, 5, 10, and 20 ppm $CdCl_2$ ° 2½ H_2O was determined. Cadmium treatment significantly reduced relative conductivity of excised stem sections. The reduction was shown to be caused by a progressive decrease in differentiation of water conducting xylem tissue, a reduction in diameter of vessel and tracheid elements, and partial occlusion of xylem elements by cellular debris or gums. The results of this study suggest that cadmium affects silver maple seedlings, and perhaps many other plant species, by increasing resistance to water movement in stems, and thereby imposing a water deficit in the shoot system. This study represents the first application of the parameter of relative conductivity in research on environmental pollutants.

An Interesting Pattern of Chlorosis in a Pin Oak, *Quercus palustris*. BELINDA A. SHENK and WILLIAM J. BRETT, Indiana State University, Terre Haute, Indiana 47809.——A pin oak tree 40 feet tall and 15 inches d.b.h. located on the campus of I.S.U. was found to exhibit a specific pattern of chlorosis for the past two years. The branches bearing chlorotic leaves extend out from an 80° section of the main trunk. Analysis of the chlorophyll content of the "normal" and chlorotic leaves over a two year period shows a consistent difference between the two types of leaves ($\bar{x} = 3.34$ mg/gr wet we normal leaves versus $\bar{x} = 1.33$ mg/gr wet we for chlorotic leaves). The relationship of the tree to surface features, cement covered soil as opposed to grass covered soil, suggests several possible explanations for the chlorosis.

Analyses of sap content and of soil borings will be run to determine possible deficiencies.

Vascular Patterns in Euphorbia Pteroneura. STEVEN SENGER and S. N. POSTLETHWAIT, Department of Biological Sciences, Purdue University, West Lafayette, Indiana 47907.——The pattern in which vascular tissue branches from the vascular cylinder to a leaf and the accompanying axillary bud was investigated by serial sectioning. The cylinder is a 6-8 sided polygon with the vascular tissue at the vertices organized into a pointed bundle, corresponding to the ribs on the stem. Three of these point bundles emerge from the cylinder and extend into the leaf. The tissues which formed the two sides of this polygon connecting the three points then come together to form a new cylinder which enters the axillary bud just above the leaf. Before this cylinder penetrates the bud, however, it has already taken on the form of a polygon with distinct point bundles. The same pattern is again found in the flower in the vascular branching to the stamens.

The Effect of Prostaglandins on Photosynthesis

R. Barr and F. L. Crane
Department of Biological Sciences
Purdue University
West Lafayette, Indiana 47907

The lipid composition of chloroplasts is well known (1,3,5,10,14, 16,17). Chloroplast lipids consist mainly of mono- and diglycerides (5,16) fatty acids (1,11) and a sulfolipid (5), but very little phospholipid. Fatty acids, particularly unsaturated ones like linoleic and linolenic acids inhibit the Hill reaction in isolated chloroplasts (7, 12,13). This inhibition has been associated with dark- or light-induced chloroplast volume and pH changes in photosystem II (18,19) or chloroplast aging (8,9,10,15). Its effects are concentration-dependent (13,19). This inhibition can be reversed by manganese (20). Higher concentrations of fatty acids are required for PS I than for PS II inhibition in chloroplasts (7,8,19).

Neutral lipids are necessary for the maintenance of membrane integrity because upon heptane extraction, which removes various lipids from chloroplast membranes, PS I is inactive unless triglycerides containing C_{18} fatty acids and plastocyanin are added to extracted chloroplasts (6).

The purpose of the present study was to explore the effects of 4 different prostaglandins PG A_2, PG B_2 PG E_2 and PG $F_2\alpha$, on chloroplast activity, on the assumption that since prostaglandins elicit such opposite reactions as constriction or relaxation in muscle tissues, more specific responses might be obtained in chloroplasts than a nonspecific lipid effect. As the following data show, such proved to be the case.

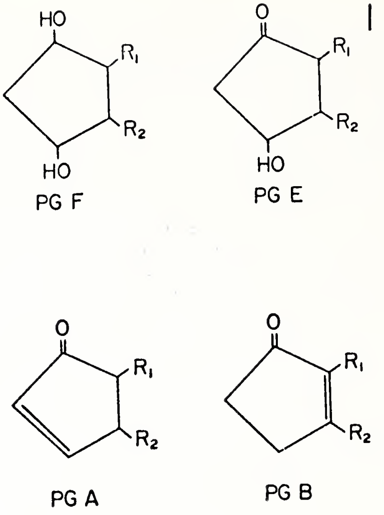
Materials and Methods

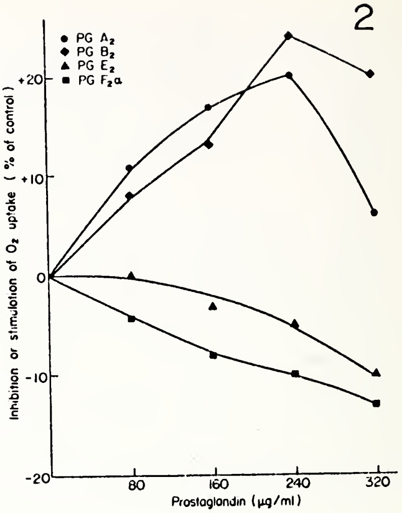
Chloroplasts were made from market spinach in 0.4 M sucrose and 0.05 M NaCl as previously described (4). Oxygen evolution or uptake in the various photosystem I and II assays was measured with a Yellow Springs Instrument oxygen monitor equipped with a Clark-type electrode as previously described (4). Reaction mixtures for the various assays are indicated in figure legends. Prostaglandins were added to the water-jacketed cell in ethanol not to exceed 5% by volume. All reaction mixes were incubated 2 min. before irradiation with light.

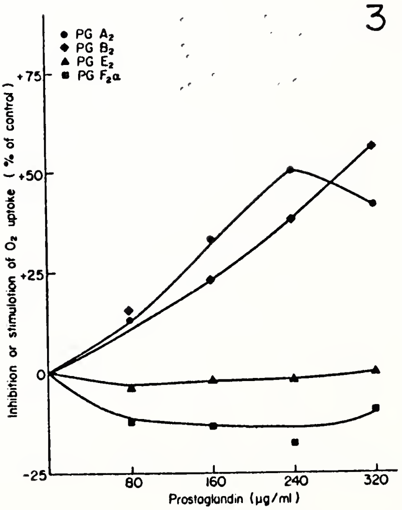
Prostaglandins were the gift of Dr. John Pike of Upjohn Pharmaceutical Co. of Kalamazoo, Michigan.

Results and Discussion

The basic structures of the 4 types prostaglandins used in this study are shown in Fig. 1. In animal tissue prostaglandins arise from the unsaturated fatty acids, such as linoleic acid, through oxygenation







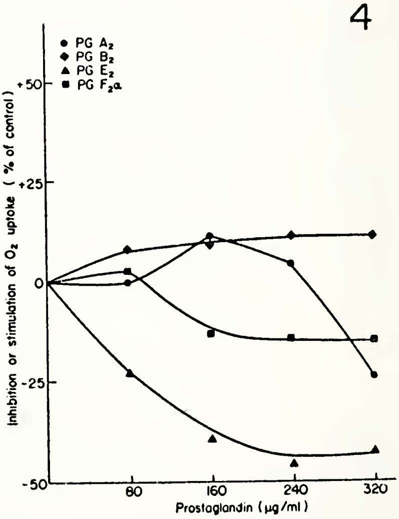
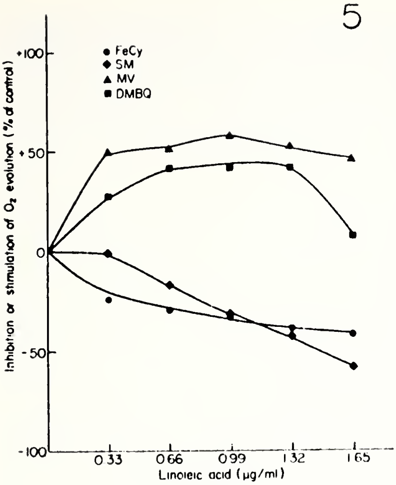


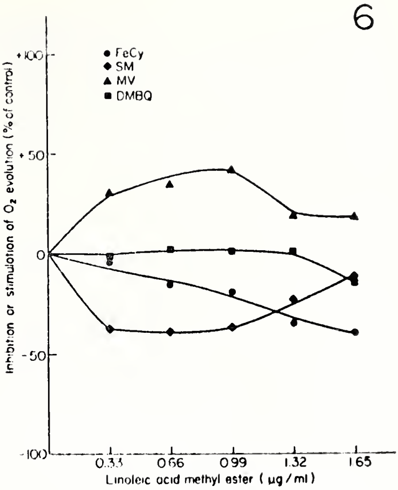
FIGURE 1. *The basic chemical structures of the prostaglandin A, B, E and F types according to Andersen (2).*

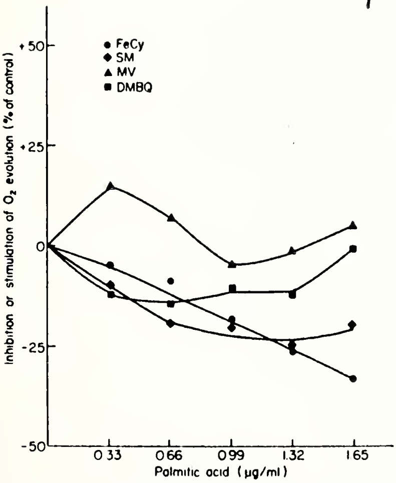
FIGURE 2. *The effect of prostaglandins A_2, B_2, E_2 and F_2a on the ascorbate plus DAD→methylviologen reaction in photosystem I of spinach chloroplasts. The reaction mixture contained in 1.5 ml total volume: chloroplasts (50 ug chlorophyll), Tris-Mes, 25 umoles, pH 8, 0.3 umoles MV, 1.2 umole DCMU, 1.5 umoles Na ascorbate and 0.1 mg DAD.*

FIGURE 3. *The effect of prostaglandins A_2, B_2, E_2 and F_2a on the ascorbate plus TMPD→methylviologen reaction in photosystem I of spinach chloroplasts. Reaction conditions as in Fig. 2 except 10 ug TMPD in place of DAD.*

FIGURE 4. *The effect of prostaglandins A_2, B_2, E_2 and F_2a on the ascorbate plus ferrocyanide→methylviologen reaction in photosystem I of spinach chloroplasts. Reaction conditions as in Fig. 2 except 0.45 mmole ferrocyanide added in place of DAD.*







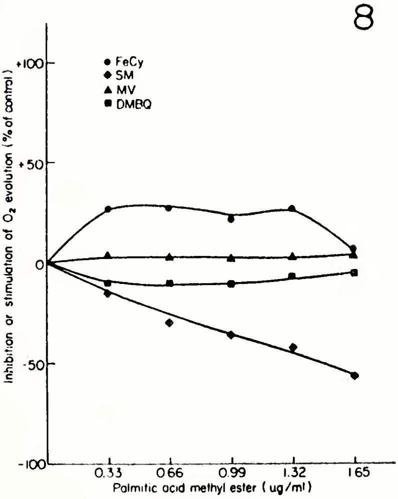


FIGURE 5. *The effect of various concentrations of linoleic acid on 4 different photosystem II reactions in spinach chloroplasts. The reaction mixture (1.5 ml total volume) for the* $H_2O \rightarrow$ *methylviologen reaction contained: chloroplasts (50 ug chlorophyll), Tris-Mes, 37.5 umoles, pH 7;* NH_4Cl, *2 umoles;* $MgCl_2$, *2 umoles; MV 0.3 umoles. The reaction mixture for the ferricyanide reduction-associated* O_2 *evolution contained the above ingredients except 2.5 umoles ferricyanide in place of MV and 0.6 umoles DBMIB. The reaction mixture for the dimethylbenzoquinone reduction by PS II contained all the ingredients as for the ferricyanide reaction mixture except 5 umoles DMBQ in place of ferricyanide. The reaction mixture for the silicomolybdic acid reduction contained chloroplasts and buffer as above but 0.2 mg SiMo in place of ferricyanide or DMBQ and 1.2 umole DCMU in place of DBMIB.*

FIGURE 6. *The effect of various concentrations on linoleic acid methyl ester on 4 different photosystem II reactions in spinach chloroplasts. Reaction conditions as in Fig. 5.*

FIGURE 7. *The effect of various concentrations of palmitic acid on 4 different photosystem II reactions in spinach chloroplasts. Reaction conditions as in Fig. 5.*

FIGURE 8. *The effect of various concentrations of palmitic acid methyl ester on 4 different photosystem II reactions in spinach chloroplasts. Reaction conditions as in Fig. 5.*

of arachidonic acid, cyclization and various minor transformations into the different types of prostaglandins (2). They are basically lipophilic in exerting their effect upon PS I in spinach chloroplasts (Fig. 2-4). Prostaglandins E_2 and $F_2\alpha$ inhibit the successive PS I reactions from plastoquinone through P700 to the methylviologen acceptance site in the electron transport chain.

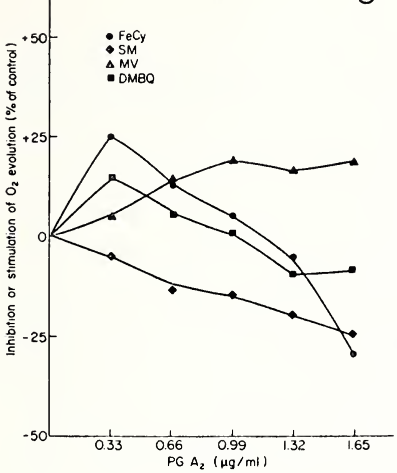
In the 3 PS I reactions tested—ascorbate plus DAD→MV, ascorbate plus TMPD→MV, and ascorbate plus ferrocyanide→MV—5-45% inhibition by prostaglandins was noted in concentrations higher than those reported previously for linoleic or palmitic acid (19). Prostaglandins A_2 and B_2, on the other hand, stimulate the 3 reactions tested by 5-55%. It is interesting to note that specific prostaglandin structure can be associated with stimulation or inhibition of the ascorbate + DAD→MV, ascorbate + TMPD→MV and the ascorbate + ferrocyanide→MV pathways: those prostaglandins (A_2 and B_2) which have an unsaturated bond in the cyclopentane ring with no hydroxyl groups attached to the ring can stimulate these reactions while PG E_2 and $F_2\alpha$ which have no unsaturations in their ring structures but have hydroxyl groups attached to the ring are inhibitory. Linoleic acid and its methyl ester (Fig. 5,6) and palmitic acid with its methyl ester (Fig. 7,8) generally show stimulation of PS II reactions, except inhibition is seen in the DCMU-insensitive pathway of silicomolybdate reduction. The H_2O→MV pathway which encompasses both photosystems is also stimulated. Ferricyanide reduction by PS II can be stimulated by the addition of palmitic acid methyl ester or inhibited by the other compounds.

The prostaglandin effect on PS II activity is shown in Fig. 9-12. Here again, as in PS I, PG A_2 and PG B_2 stimulate the overall H_2O→MV reaction over its combined PS II and PS I pathway. So does PG E_2 in low concentrations (0.33-1.65 μg/ml), but higher concentrations (80-32 μg/ml) inhibit the reducing side of PS II (Fig. 2-4). Dimethylbenzoquinone reduction by PS II is inhibited by all prostaglandins in the low concentrations. Ferricyanide reduction by PS II in presence of DBMIB to stop electron flow through PS I can be stimulated by low concentrations of the various prostaglandins, except PG $F_2\alpha$ and PG B, but it is inhibited to varying degrees when the prostaglandin concentration reaches 1.65 μg/ml.

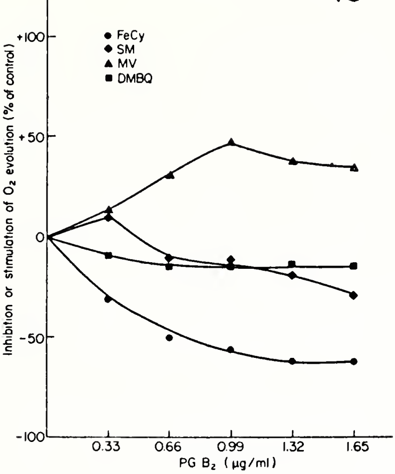
Silicomolybdate reduction by PS II in presence of DCMU, when silicomolybdic acid accepts electrons from Q, the primary electron acceptor in PS II, is inhibited by all but PG F_2 α.

The data reported in this communication can be explained if cyclic electron flow around PS II is inhibited. Since prostaglandins A_2, B_2 and E_2 inhibit silicomolybdate reduction by PS II in presence of DCMU, this implies inhibition of a postulated PS II cycle. When cyclic electron flow in PS II is inhibited, there is a faster transfer of electrons in the forward direction toward PS I; hence stimulation of PS I rates can be expected, unless specific inhibition sites occur on the pathway, as shown by the action of PG E_2 in PS I reactions. According to the hypothesis, a converse effect takes place when a compound stimulates silicomolybdate reduction by PS II. In this case a slowdown of all forward photosynthetic reactions would be expected, as demonstrated by the addition of PG $F_2\alpha$ to PS I reactions. Thus prostaglandins may provide evidence that the rate of photosynthesis is regulated by internal chloroplast control mechanisms.

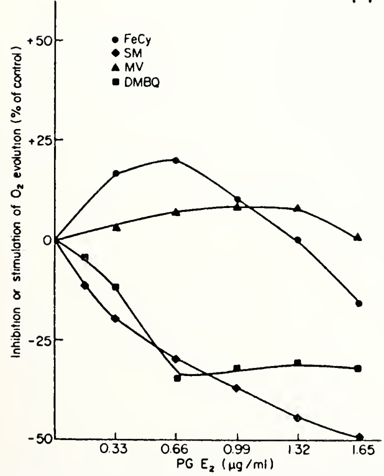
9



10



11



12

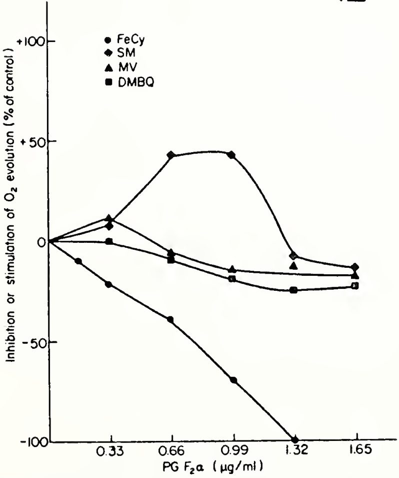


FIGURE 9. *The effect of prostaglandin A_2 on 4 different photosystem II reactions in spinach chloroplasts. Reaction conditions as in Fig. 5.*

FIGURE 10. *The effect of prostaglandin B_2 on 4 different photosystem II reactions in spinach chloroplasts. Reaction conditions as in Fig. 5.*

FIGURE 11. *The effect of prostaglandin E_2 on 4 different photosystem II reactions to spinach chloroplasts. Reaction conditions as in Fig. 5.*

FIGURE 12. *The effect of prostaglandin $F_2\alpha$ on 4 different photosystem II reactions in spinach chloroplasts. Reaction conditions as in Fig. 5.*

Abbreviations used:

DAD-diaminodurene; DBMIB-2,5-dibromo-3-methyl-6-isopropyl-p-benzoquinone; DCMU-3-(3,4-dichlorophenyl)-1,1-dimethylurea; DMBQ-2,5-dimethylbenzoquinone; MV-methylviologen; SM-silicomolybdic acid; PS I-photosystem I; PS II-photosystem II; TMPD-N,N,N,N'-tetramethyl-p-phenylene diamine.

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Some Algae of Lake Galatia, Grant County, Indiana (exclusive of diatoms)

GAIL E. SHEW[1] and LELAND L. HARDMAN[2]
Ball State University, Muncie, Indiana

Abstract

A qualitative algal survey of an 18 acre lake in central Indiana was conducted from July 23, 1975 through January 28, 1976. Eighty-seven algal species in 39 genera were collected and identified. Sixteen of the algae encountered are thought to be new reports for the state of Indiana. These new reports will be added to *A Check List of Algae from Indiana, 1929 to 1971 (inclusive)* compiled by F. K. Daily, 1972.

Introduction

An extensive review of the existing literature has failed to locate any detailed studies or appropriate species lists of the algal flora of Lake Galatia, Grant County, Indiana. Daily (3) did report a bloom of *Oscillatoria curviceps* Agardh 1824 on this lake. Drouet (4) in his *Revision of the Classification of the Oscillatoreaceae* cited an additional species, *Porphyrosiphon notarissii* (Meneghini) Kuetzing collected by Daily in 1939 but not previously reported by him.

The primary goal of this research was to qualitatively study the algae of Lake Galatia during a six month period and to compile a species list of the encountered algae.

Study Area

Lake Galatia is an 18 acre (1) body of water located at the intersection of County Roads 800 S/ 500 E (NE ¼ NE ¼ Section 23 Township 25 N R8E) in Grant County, Indiana. The lake measures 266 meters wide at its widest point and 500 meters long. The soil of the area is dark-colored Carlisle Muck (5) having a high moisture holding capacity which contributes to the boggy nature of the lake.

Methods and Materials

The survey was conducted over a six month period between July 23, 1975 and January 28, 1976. Sampling was done on a bi-weekly (every two weeks) basis during the first four months, with monthly samples collected during December and January.

In an effort to adequately sample all the niches of the lake, five stations were established as permanent collecting sites for the study. These stations were chosen to represent the various observed physical characteristics of the lake. Four of these stations were located in open water ranging in depths from 1.5 to 2.5 meters. The fifth station was located in the extreme northeast end of the lake, where a number of dead trees remain in the water along with several submerged and partially submerged logs. The maximum depth at this station was 1.0 meter.

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[1] Present address: 22 High St., Milford, Ohio 45150.

[2] Present address: Department of Agronomy and Plant Genetics, University of Minnesota, St. Paul, Minnesota 55108.

The four open water stations were regularly sampled using a standard #20 or #25 plankton net. Grab samples, substrate scrapings and concentrated bulk water samples were the primary methods of collection at the fifth station.

All samples were collected in duplicate and preserved in Transeau's solution. Identifications were accomplished using both fresh and preserved materials. Laboratory identifications were carried out to the most specific taxon possible using existing taxonomic keys and following Prescott's (10) nomenclature. Portions of all samples were retained in 10 ml. vials and placed in the Herbarium at Ball State University, Muncie, Indiana.

Results and Discussion

During the study 87 algal species, varieties and forms in 39 genera[3] were identified from samples collected during the six month period (July 23, 1975 through January 28, 1976). These species represent four phyla, four classes, 11 orders, and 22 families. The largest number of species encountered belonged to the phyla Chlorophyta, Cyanophyta, Pyrrophyta and Euglenophyta, respectively.

Seven families — Scenedesmaceae, Oocystaceae, Oscillatoreaceae, Desmidiaceae, Hydrodictyaceae, Chroococcaceae and Nostocaceae predominate in the flora of the lake and sixty-five of the total species encountered are in these seven families. The remaining twenty-two species are scattered in the remaining fifteen families. This illustrates the diversity of algae present in Lake Galatia but also illustrates that the flora is dominated by a few families.

Sixteen of the algae encountered are believed to be new reports for the state of Indiana, since they do not appear in the check lists provided by C.M. Palmer (6,7,8,9), the *Check List of Algae Recorded from Indiana, 1929 to 1971 (inclusive)* (2) or in any later literature. A qualified list of these algae appear in Table 1. In some instances it is the variety rather than the species which is new to the state. The author recognizes the fact that by using the nomenclature of other authorities in the field, certain algae would not be included in this list. For instance, Drouet (4) includes *Oscillatoria limnetica* Lemmerman and *Phormidium foveolarum* (Montagne) Gomont in the species *Schizothrix calcicola* (Ag.) Gomont which has been reported in the state.

A significant aspect of the algal flora of Lake Galatia is the periodic and intense blooms which occur. A series of fourteen algal blooms were noted during the study. Fifty percent of these blooms were blue-green species and generally occurred early in the summer while the greens appeared to proliferate in the fall and winter. When

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[3] A complete list of all taxa encountered may be obtained, upon request, from the author.

TABLE 1. *Algae encountered in Lake Galatia, Grant County, Indiana (from July 23, 1975 through January 28, 1976) which are considered to be new reports for Indiana.*

Species
Blue-greens:
Chroococcus minor (Kuetz.) Naegeli
Chroococcus limneticus var. *carneus* (Chod.) Lemmerman
Nostoc paludosum Kuetzing
Oscillatoria limnetica Lemmerman
Oscillatoria subbrevis Schmidle
Phormidium foveolarum (Montagne) Gomont
Desmids:
Staurastrum chaetocerus (Schroeder) G. M. Smith
Greens:
Characium obtusum A. Braun
Franceia Droesheri (Lemm.) G. M. Smith
Glenodinium Gymnodinium Penard
Glenodinium pulvisculus (Ehrenb.) Stein
Lagerheimia quadriseta (Lemm.) G. M. Smith
Pediastrum duplex var. *reticulatum* Lagerheim
Scenedesmus abundans var. *brevicauda* G. M. Smith
Tetraëdron muticum (A. Braun) Hansgirg
Tetraëdron regulare var. *torsum* (Turner) Brunnthaler

the sampling began on July 23, 1975 a bloom of *Coelosphaerium Naegelianum* Unger was in progress and continued without noticeable decline through August 20, 1975. The longest sustained blooms were those of *Tetraëdron minimum* and *T. muticum* (A. Braun) Hansgirg which were first recorded on September 3, 1975 and continued through the November 25, 1975 sampling date.

The species list resulting from this study is typical of that which one might find in a lake of this nature in central Indiana. It should not be considered a complete or exhaustive list as the study was only conducted over a six month period of time. The species list does, however, reflect the eutrophic nature of the lake.

Acknowledgements

Thanks are extended to Mr. Ben Lewis for permission to study Lake Galatia and for the use of his boats and dock during the study. Sincere appreciation is also expressed to Terry D. Willis for assistance in collecting samples.

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Naturally Occurring Mature American Chestnut Trees *(Castanea dentata)* in Northwest Indiana

JAMES WILLUT, GAYTON MARKS, and GARLAND HICKS
Department of Biology
Valparaiso University
Valparaiso, Indiana 46383

Abstract

Three mature (14-17 m, 38-56 cm DBH) and several smaller American chestnuts were located within 200 m of one another on a farm woodland in Union Township, Porter County, Indiana. Two of the larger trees are heavily infected with the blight fungus *Endothia parasitiea*. *E. parasitica* isolated from these trees is similar in appearance and invasiveness to highly pathogenic strains. The third mature tree shows no sign of infection.

Introduction

Three mature American chestnuts (*Castanea dentata* Borkh.), recently discovered five miles west of Valparaiso, Indiana, in Union Township (R6W T35N Sect. 19 NW quarter) are on wooded sites bordered by cultivated fields. Two are infected by the chestnut blight fungus, whereas the third shows no signs nor symptoms of the disease.

Endothia parasitica (Murr.), the causative agent of the chestnut canker disease, was first described in New York City in 1904. The fungus came to North America from Asia and by 1940 the disease had spread through the entire range of the chestnut. Uncultivated, mature trees are very rare today though small trees are quite common, particularly in the Appalachian region (e.g. 4).

These most unusual trees constitute an *in situ* laboratory for diverse studies of both host and pathogen. Initially, investigations were restricted to positive identification of tree and fungus, to recording the progress of the infections and to obtaining presumptive information about possible disease resistance of host or degree of virulence of the *E. parasitica*.

Methods

The trees were identified as American chestnuts through use of keys and by comparison to herbarium specimens. Tree A, arbitrarily designated, is about 17 m high and has a DBH of 44 cm (17.5 in); B is 14 m, DBH 56 cm (22 in); C is 17 m, DBH 38 cm (15 in). Four smaller trees, 6-11 m, DBH 5-13 cm (2-5 in), were located within 16 m of C. The trees were observed regularly from March through October to determine characteristics of the infection through one full growing season.

E. parasitica was isolated from a canker on A. Potato dextrose agar (PDA), Sabouraud's agar and host tissue were used to culture the fungus. Identification was made by analysis of morphology in the various media and confirmed by comparison to a known culture.

Invasiveness of this isolate in freshly cut host twigs was compared with that of a known virulent strain of *E. parasitica.* Sets of twigs from each of trees A, B and C were inoculated with both fungus strains by the methods of Clapper (3). PDA plugs about 7 mm in diameter containing mycelium and spores were inserted aseptically, surface side down, in cuts in the twigs. The inoculation points then were sealed with Parafilm and the cut ends of the twigs were maintained in water. The experimental infections were observed for several weeks to discern similarities in growth rate or growth characteristics.

Results

The mature trees are situated within 200 m of one another in a roughly triangular formation with A and B at the peripheries of wooded areas and C in the center of a small bottomland wooded tract. A and B are heavily infected with *E. parasitica* and each has several cankers. C apparently is uninfected, as are the smaller trees. The predominant trees of the area are black oak, black cherry, small-fruited hickory, black walnut and sugar maple. Three secondary hosts of *E. parasitica,* shagbark hickory, red maple and staghorn sumac, are also common.

There are two large infections on the trunk of A. One, 3 m from the ground, measures 53 x 86 cm at a trunk circumference of 124 cm. This infection extends to a lateral branch which has been girdled and killed. The tissues at the center of the canker are well decomposed and some bark has fallen from it. Much of the canker is covered with *Endothia* pustules which contain pycnidia and characteristic spore horns. A second infection, 51 x 46 cm, is 5.8 m from the ground at a trunk circumference of 114 cm. This canker appears younger than the first and consists of a slightly raised area with intermittent pustules. The bark here is not severely decomposed or split.

The one large infection on the trunk of B is 3.7 m from the ground and measures 33 x 25 cm at a trunk circumference of 124 cm. It consists of intermittent patches of pustules and is less developed than the two cankers on A. A second canker girdled and killed this year a lateral branch which joins the trunk at a height of 3.4 m. Wilt, chlorosis or similar manifestations are inapparent on all chestnuts; the trees outwardly appear to be thriving.

Our isolate of *E. parasitica* was morphologically indistinguishable on host tissue or on artificial media from known virulent strains of *E. parasitica.* The characteristics of the experimental infections produced by both strains of *E. parasitica* were identical on all twigs from all three trees, which suggests that our isolate and the known virulent strain of the fungus possess similar invasive capabilities.

Discussion

These chestnuts may have survived because they were isolated for a number of years at the fringe of the former chestnut range (5) and have only recently become diseased. However, the infections are well established and are progressing, albeit slowly, on trees A and B. The rotted condition of the canker on A is indicative of a much older infection than one that would hypothetically result from the 16 cm annual growth rate reported by Anderson (1) in 1914. The apparently uninfected state of tree C in an area of high and sustained *Endothia* inoculum is particularly intriguing. Indeed, this tree may have significant natural resistance to the blight, though the growth of *Endothia* in the cut twigs would not suggest this.

It is most unlikely that these chestnuts are hybrids with the disease resistant Chinese chestnut (*C. mollissima*) or Japanese chestnut (*C. crenata*). Their character is solely that of the American species. Furthermore, the trees are located in a random pattern in a small but fairly wild area which is a good distance from dwellings or roads. This suggests strongly that they were free from man's horticultural influence and occurred naturally.

Tree B, left photograph, is typical in size of all three mature chestnuts. Note root sprout at base, common to such diseased chestnuts. The apparently uninfected tree is shown at right.

Tentative future work will include attempts to propagate the uninfected tree, to study the influence that *Endothia* toxins (2) may have in these infections and to conduct further tests for fungal virulence. These trees lie in prime development land; chain saws may terminate this research rather abruptly.

Acknowledgments

We thank John and Tom Peabody who, at the suggestion of Marion T. Jackson, brought the location of these trees to our attention. We also thank Richard Jaynes for providing *E. parasitica* cultures.

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Gaultheria procumbens at Pine Hills, Indiana —Its Measured Decline, 1951-1971

Daniel B. Ward
Department of Botany, University of Florida
Gainesville, Florida 32611

Abstract

Perimeters of *Gaultheria procumbens* L. (Wintergreen) populations in Pine Hills Natural Area, Montgomery County, Indiana, were mapped at decade intervals from 1951 to 1971. Associated dominant trees were measured, and their date of "zero diameter" was calculated. *Gaultheria* densely covered an area of 204 m^2 in 1951, continued healthy with an area of 307 m^2 in 1961, and declined precipitously to 26.3 m^2 plus 23 separate plants in 1971. Suggestions are made that survival of *Gaultheria* at Pine Hills is associated with the formation of acid soils weathered from Borden sandstones and protected from calcareous leaching by a deeply meandered stream system, and that its near-disappearance by 1971 is accompanied by re-establishment of hemlock and pine. *Cornus rugosa* Lam. (Roundleaf Dogwood) on the adjacent cliffs of Borden sandstone remained nearly constant, with a population of 147.

Introduction

Gaultheria procumbens L., or Wintergreen, is a northern plant that ranges from Newfoundland to Manitoba and extends south in the Appalachians to northern Georgia and Alabama. In Indiana it is largely a post-glacial relict (3), known only in five countries south of the northern third of the state (2). In the first discovered (1) and perhaps the best known of these stations, a population in the Pine Hills Natural Area, Montgomery County, the species was observed, during a recent 20-year period, to be undergoing a rapid decline in numbers and vigor, suggesting that local extinction may be imminent.

The Pine Hills Natural Area, in southwestern Montgomery County, Indiana, is a region of steep cliffs, cool north-facing slopes, and well-leached acid ridges. The physiography has been described by Smith (8), the vegetation has been mapped by Friesner and Potzger (4), and the flora has been carefully inventoried by McCormick (6). Pine Hills is most noted for an impressive series of incised meanders of Indian Creek and the subsidiary Clifty Creek, tributaries of Sugar Creek, the principal drainage channel of the region. Pleistocene meltwaters deeply entrenched Sugar Creek in the glacial deposits and the underlying bedrock, and these tributary streams cut down to the same level, while still conforming to the meandering course that they had established in the mature pre-glacial topography. At seven places in the Pine Hills area these streams bend back upon themselves, or upon each other, to form steep sided ridges or "backbones" up to 70 m long and 33 m above the stream beds. In 1960 The Nature Conservancy completed purchase of Pine Hills, then presented it to the State of Indiana for maintenance in perpetuity as a wilderness (6). It was appropriately given a rating of "1" by Lindsey et al. (5), indicating the highest evaluation as a natural area.

Description of Mill Cut Backbone

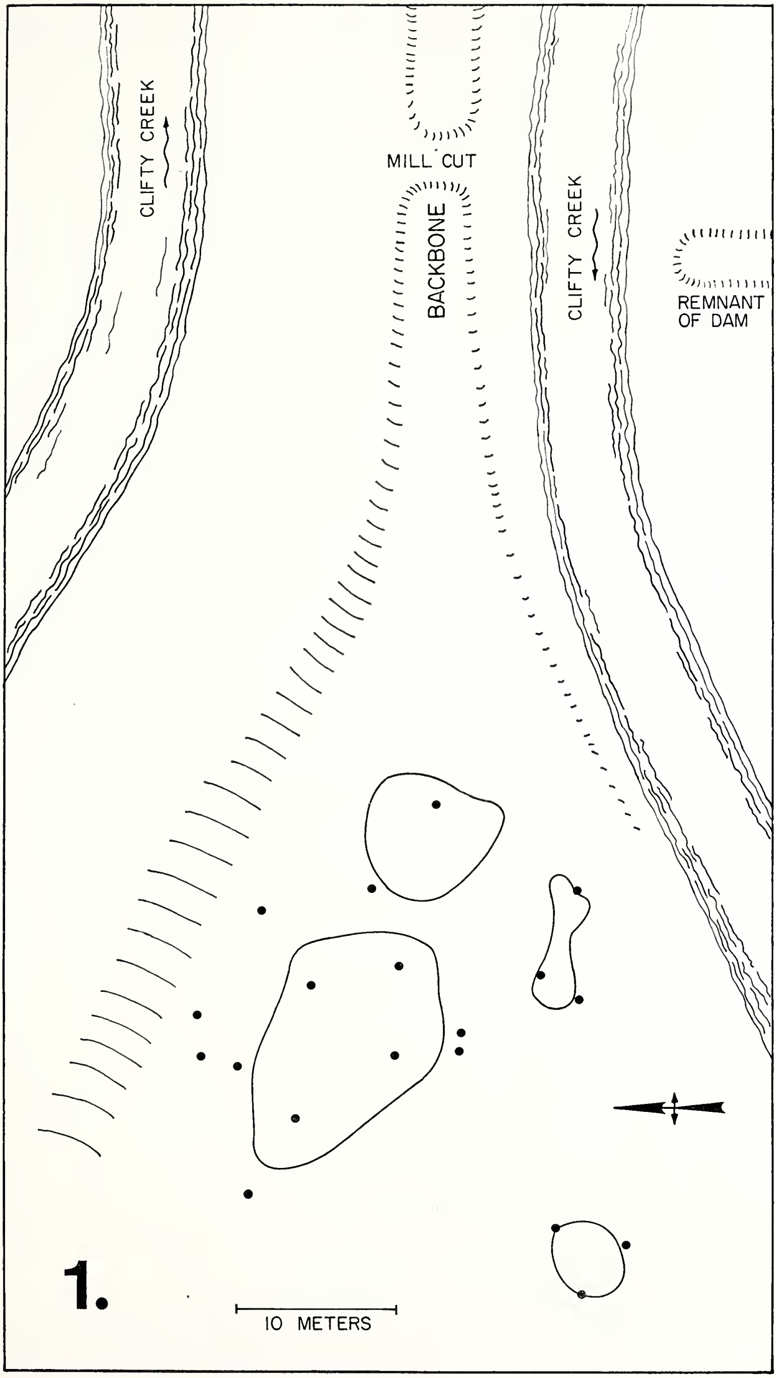
The backbone known as "Mill Cut" is formed by a looping bend of Clifty Creek (Fig. 1). Clifty Creek, in its headwaters flowing generally northward, abruptly changes direction to the west, circles widely to the north and east, and approaches the course of its westward channel before again turning northward. The westward and eastward legs of the creek thus flow in opposite directions but in close proximity. They are separated by a ridge or wall of Borden sandstone (8) closely approached on the southern exposure by the west-flowing channel and somewhat less closely on the north by the east-flowing lower course of the stream. This wall has been formed by the progressive and relatively rapid erosion of the sandstone by the flowing stream, aided by the winter freeze-and-thaw spalling of large stone plates parallel to the exposed surface, a distinctive property of the Borden formation. This erosion, no doubt much accentuated in times of glacial run-off, has produced a channel that varies in depth from about 9 or 10 m at the lowest point of the backbone to over 20 m at the east and where the backbone merges with the adjacent upland.

The millcut, a man-made square notch through the narrowest and lowest portion of the backbone, is about 6 m deep and 3 m wide. It lacks 3 m of reaching the bed of the west-flowing channel (Fig. 1). The cut was made in 1868 to supply water power to a small woolen mill on the terrace of Clifty Creek just north of the Mill Cut Backbone (6). A crib dam of hemlock logs, filled with rock rubble, was built across Clifty Creek on its westward leg just downstream from the cut; a low mound outlining this dam was still discernible in 1971. Water impounded by this dam passed through the cut, along a wooden flume, to an overshot wheel in the mill. The mill was discontinued and the equipment removed in 1873. Except for the millcut, traces of the dam, and a remnant of the access road up the slope to the south of the backbone, the only present indications of human disturbance are in subtle features of plant distribution.

The *Gaultheria* Population

The only *Gaultheria* in the Pine Hills region grows in the loop formed by the circling Clifty Creek, just west of the millcut. As the creek entrenched itself in the Borden formation it swung ever wider in the westward portion of its bend. It left a knoll at the west end of the backbone, the north side of which was continuous with the backbone's north face, although less sheer and more vegetation covered, with the south side sloping gradually to a low bench just above the west-flowing leg of the stream. It is on this gradual south-facing slope that the *Gaultheria* has survived.

FIGURE 1. *Map, showing Mill Cut Backbone, Pine Hills, and associated stands of* Gaultheria *in 1951. Clifty Creek flows from the upper right, downward along the south face of the Backbone, then circles widely (off the plate) to reappear on the north face of the Backbone. Within this loop of Clifty Creek a knoll (indicated by hatch lines) extends eastward to a cut where a millrace was once located. The* Gaultheria *occurs in four separate colonies (represented by the solid lines). Major trees are indicated by dots.*


CLIFTY CREEK
MILL CUT
BACKBONE
CLIFTY CREEK
REMNANT OF DAM
10 METERS

1.

The slope is sparsely covered with mature but somewhat stunted trees. Toward the crest, northern red oak (*Quercus borealis*), black oak (*Q. velutina*), and a few large hemlock (*Tsuga canadensis*) predominate, while lower down white oak (*Q. alba*) and white pine (*Pinus strobus*) appear. Beech (*Fagus grandifolia*) and sugar maple (*Acer saccharum)* are on the bench near the stream. Linden *(Tilia americana*), tulip-tree (*Liriodendron tulipifera*), redbud (*Cercis canadensis*), and blue-beech (*Carpinus caroliniana*) occur only at the stream edge, below the *Gaultheria* population. The crest of the slope bears a rich understory, containing black gum (*Nyssa sylvatica*), flowering dogwood (*Cornus florida*), red cedar (*Juniperus virginiana*), witchhazel (*Hamamelis virginiana*), and wild hydrangea (*Hydrangea arborescens*). These are replaced lower on the slope by shadblow (*Amelanchier arborea*), ironwood (*Ostrya virginiana*), red maple (*Acer rubrum*), mapleleaf viburnum (*Viburnum acerifolium*), sassafras (*Sassafras albidum*), partridgeberry (*Mitchella repens*), and running euonymus (*Euonymus obovatus*). Wintergreen (*Gaultheria procumbens*) occurs only on this slope, below the crest and extending to the stream bench.

Circumference measurements of the larger trees of the *Gaultheria* slope give a degree of insight to the earlier appearance of the area. Sixteen individuals were measured for the entire 20-year period, several others dying in the interim. Perhaps the most meaningful statistic derived from these measurements, in light of the need to understand the earlier vegetational history of the slope, is the date of "zero diameter," a calendar date obtained by extrapolating backward the tree's growth in diameter as measured over the last 20 years. This figure is understandably problematical, but places less stress on the specimen trees than increment borings, and is the only approach available in a protected forest.

The only measured hemlock in the area of the *Gaultheria* population, of several large individuals along the crest of the knoll, gave a zero diameter date of 1671, a compelling statement of its presence throughout historic times. Four white pines gave less conclusive dates of 1812, 1838, 1895, and 1927. The two black oaks with full data gave dates of 1854 and 1858; larger individuals present in 1951 died before 1971. Six white oaks yielded 1704, 1815, 1821, 1832, 1887, and 1901. A solitary beech and a sugar maple showed little growth during the study period.

The aspect of the *Gaultheria* slope changed markedly during the 20 years it was under observation. It was first sunny and open, with *Gaultheria* forming dense green mats that were vigorous and sharply delimited. The slope became progressively more thickly covered with sapling hemlocks (most of them becoming 2-4 m tall with 1-3 cm basal diameters) plus a smaller number of young white pines. At the final survey no more than 5-15% of the soil surface was exposed to the noonday sun. The surviving *Gaultheria* plants were scattered in this dense thicket.

In June, 1951, in 1961, and in 1971, the *Gaultheria* population was carefully mapped. Larger trees served as reference points, and their diameters were measured on each occasion. The perimeters of the

Gaultheria colonies were recorded, a simple task on the open slope of 1951, but less easily achieved in the young hemlock and pine thicket of 1961. By 1971 the colonies had fragmented, with a meaningful perimeter no longer persisting; in this situation individual plants were located and marked only with difficulty.

The 1951 observations recorded *Gaultheria* in four wholly distinct and sharply demarked colonies (Fig. 1). These ranged in area from 130 m^2, to 16 m^2 and together covered 204 m^2. The horizontal stems were closely entangled, with numerous forkings and abundant evergreen foliage. They were estimated to have the capability of extending the colony about 10 cm in a single year, a figure smaller than that indicated by later measurement.

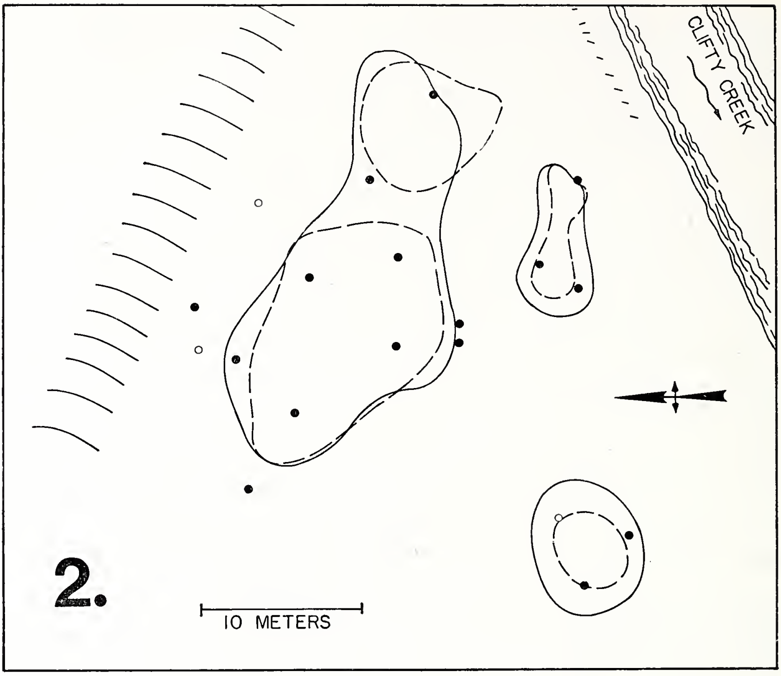
The 1961 observation yielded a similar pattern (Fig. 2). Each of the four colonies was slightly enlarged, two of them having met and become one. The total area covered was 307 m^2. The maximum distance *Gaultheria* was found outside the 1951 perimeter was approximately 150 cm, suggesting an annual rate of spread of 15 cm. The colonies remained dense, in some locations very much so, but a future decline was adumbrated by the disappearance of *Gaultheria* from part of the easternmost portion of the population.

By 1971 the situation had changed markedly (Fig. 3). The *Gaultheria* colonies had lost their discrete outlines, and in most of the area the plants had disappeared. No *Gaultheria* was found on the site of the previously smallest colony and only two plants survived of the other smaller colony. The formerly extensive merged colony was reduced to a small area of 16.3 m^2, containing no more than 5 to 10 leaf-bearing stems/m^2, plus some 21 scattered plants. No plants were found more than insignificant distances outside the 1961 perimeter.

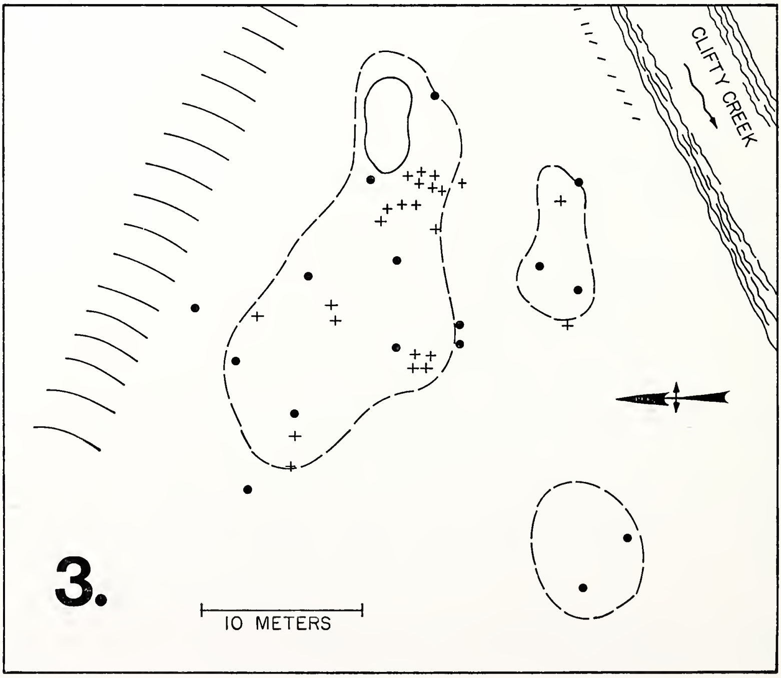
Discussion

Speculation as to the causes of disappearance of a plant species is usually difficult because of the absence of time-coupled quantitative records. In this instance, with population data spanning 20 years, some degree of credibility may perhaps be attached to suppositions drawn from historic events, although the full causative factors remain elusive.

It may be assumed, from the absence of *Gaultheria procumbens* elsewhere in the Pine Hills region, that this boreal species has persisted on the south-facing slope at the west end of the Mill Cut Backbone since the glacial recession. With decomposition, the Borden sandstones yield an acid soil which appears a necessary factor for the persistence of white pine, hemlock, and very possibly *Gaultheria*. Hemlock and pine seedlings are known to prefer soil of high acidity. At Pine Hills, Potzger and Friesner (7) found hemlock reproduction to be most vigorous on soils with pH near 4.5. The predominance of hemlock and pine on the slopes of the various backbones of the Pine Hills, and particularly on the knolls which rise at the ends of these backbones within the loop of the encircling stream, a distribution which has been excellently mapped and portrayed by Friesner and Potzger (4), may be accentuated by the absence of calcareous seepage from the overlying soils


CLIFTY CREEK
10 METERS

2.


CLIFTY CREEK
10 METERS

3.

of glacial origin on the surrounding uplands. The meandering streams with their deeply entrenched channels effectively isolate these backbones and their knolls from sources of non-acid influence.

The presence of *Gaultheria*, a northern plant, on a south-facing slope is thus not an anomaly of distribution. The species may have a requirement for acid soil that is more critical for its survival than is the coolness and moisture of other sites in the Pine Hills area.

Almost surely the slope where the *Gaultheria* now grows was until historic times forested predominantly with hemlock, as presently are similar sites near the other backbones. In pioneer days the low worth of hemlock timber and the difficult terrain, and in more recent times a series of protective landowners, have preserved the forest cover of the Pine Hills. The absence of mature hemlock from the *Gaultheria* slope at the west end of Mill Cut Backbone seems associated with the commercial exploitation of the site during construction of the woolen mill in 1868. Although the millcut did not disturb the *Gaultheria* and the mill itself was on the opposite side of the backbone from the slope on which it grows, the construction of the log crib dam must have had significant impact.

Beyond the statement that the dam was once about 4.6 m tall (6), there is no basis for calculation of the volume of timber required for an effective barrier to the flow of Clifty Creek. Nor is there an estimate for the quantity of hemlock that once stood on the slope just downstream from the dam site. But there seems little reason to doubt that the most convenient source of materials for the dam would have been the immediately available easily-worked softwoods on the *Gaultheria* slope. It is a comfortable speculation that this slope was shorn of its hemlock and pine in 1868, with the task completed before reaching the few large hemlocks now standing on the crest. The age of the other trees suggest that some individuals were a minor component of the original hemlock forest, while others, and perhaps all of the black oak, came in at or soon after the time of disturbance.

A possibility exists that removal of the hemlock from the slope at the west end of the millcut, rather than accelerating the decline of the *Gaultheria*, may indeed have been the agent that prolonged its survival into the present century. When first measured in 1951, the *Gaultheria* was growing vigorously in sharply delimited colonies, scarcely the pattern to be anticipated in a static or declining situation. Nor could such a vigorous condition be of long duration, for with the plants capable of spreading at the rate of 10 to 15 cm per year, no more than one or two centuries would have been required for it to become an omnipresent groundcover on the Mill Cut knoll. Since no point in the 1951 colonies was more than 4.9 m from the periphery, by the smaller estimate of

FIGURE 2. *Map, showing status of* Gaultheria *population in 1961. The previous colonies have now expanded somewhat over the 1951 perimeters (represented by dashed lines). Trees dead since 1951 are indicated by hollow dots.*

FIGURE 3. *Map, showing status of* Gaultheria *population in 1971. The stand remains dense in only one area (enclosed by solid line); elsewhere, solitary surviving plants are represented by crosses (+).*

10 cm per year, approximately 50 years would have been sufficient for development of the largest colony. This figure may be within permissible limits of error of the 83 years that had elapsed since construction of the dam and probable logging of the *Gaultheria* slope.

If the *Gaultheria* on the Mill Cut knoll in 1868 was in a condition of decline, or at the verge of extinction, for reasons that were associated with the hemlock overstory, the removal of this timber may have been a reprive in its population trend. The *Gaultheria* plants surviving in 1868 would have undergone a resurgence that led to the vital colonies observed in 1951. Although these colonies may have been formed by the merger of smaller clones, it may be that in 1868 *Gaultheria* in the Pine Hills was reduced to as few as four surviving plants. Had the millcut not been built, and the hemlock timber removed, the present century might well have never known *Gaultheria* from Montgomery County, Indiana.

The re-establishment in the last quarter century of a vigorous young hemlock and pine forest on the slope of the Mill Cut knoll has reversed, once again, the population trends of the *Gaultheria.* Although the Wintergreen colonies were clearly vigorous in 1951, and appeared to continue so until 1961, the following decade saw an abrupt crash that coincided with the development of the conifer thicket. A continuation of this most recent trend for no more than a few years must result in the extinction of *Gaultheria* in the Pine Hills.

A Second Relict, *Cornus rugosa*

An additional plant of the Mill Cut Backbone, similarly a relict of cooler post-glacial climates, is *Cornus rugosa* Lam., the Roundleaf Dogwood. Deam (2) recorded this shrub in Indiana only in five counties along the northern edge of the state, and in Montgomery County at the Pine Hills station. It is thus even rarer in Indiana than *Gaultheria,* and proportionately more precarious in retaining its place among the subboreal vegetation of central Indiana.

At Pine Hills this *Cornus* is known only on the bare rock cliffs and dry crest of the Mill Cut Backbone, just east of the wooded slope on which the *Gaultheria* occurs. In June, 1951, an approximate tally was made of the number of plants to be seen on this limited habitat, east and west of the millcut itself, as follows: west, on north side—61 plants; on south side—38 plants; east, on north side—26 plants; on south side—0 plants. An additional 22 plants were seen on top of the backbone, yielding a total population number of 147. A count in September, 1971, gave somewhat smaller but perhaps not significantly different results, implying that *Cornus rugosa* during the two intervening decades has resisted the downward population trend of its northern associate, the *Gaultheria.*

The exposed rocks of the Mill Cut backbone are all shaley sandstones of the Borden formation (8). The southern exposure, other than for the bisection provided by the millcut, appears uniform; yet, while *Cornus* is frequent west of the cut, it is wholly absent east. A tentative explanation may lie in the location of the mill dam, just west of the cut, which would have flooded the lower portion of the cliff upstream, with capillary seepage changing the habitat of the bluff immediately above. Although the mill was removed in 1873 (6), and doubtless maintenance of the dam terminated at that time, the century since elapsed has not seen re-establishment of *Cornus* on the denuded cliff face.

Acknowledgments

I wish to express my special gratitude to Dr. Albert R. Bechtel of Wabash College who pointed out to me prior to 1951 many of the features described here, to Charles M. Lytle, now of North Carolina State University, for his assistance with the 1951 survey, to my wife Suzanne for help in 1961, and to my sons Forrest and Gordon who facilitated the mapping task of 1971.

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CELL BIOLOGY

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Purification of S-Methyl-L-Methionine:Homocysteine Methyltransferase in *Triticum aestivum* (Gramineae). JAMES E. BRYAN and BETTY D. ALLAMONG, Department of Biology, Ball State University, Muncie, Indiana 47306.——Purification procedures for S-methyl-L-methionine:homocysteine methyltransferase (EC 2.1.1.10) were investigated. Centrifugation studies at varying speeds, up to 105,000 xg, were performed and the majority of the activity was determined to be in the soluble fraction. Ammonium sulfate fractionation and gel filtration were employed to obtain a final 88-fold purification. The purity of the enzyme was checked using polyacrylamide gel electrophoresis. The molecular weight of the enzyme, was determined by gel filtration to be in the range of 35,000-42,000.

Endogenous Virus from Mouse L-Cells. R. J. BOYD, C. W. GODZESKI, and V. C. SPURLING, The Lilly Research Laboratories, Indianapolis, Indiana 46206.——The fact that mouse cells and tissues all carry tumor virus potential has been well publicized since 1958, but researchers do not seem to heed the implicit warnings. Mouse cell lines may express virus and/or virus-like particles as a result of relatively minor environmental changes. Our laboratory has found that mouse L-cells contain intracisternal type A particles and intracytoplasmic type A particles (possible precursor to the type B virus) when the serum content of the 199 medium was lowered to 2% from 5% or when $NaHCO_3$ was increased from 1.68 gms/L to 2.2 gms/L. Published reports imply that more drastic measures, e.g., halogenated pyrimidines, high serum levels, radiation, or cytotoxic agents, were required to induce endogenous virus release. This may not be so. Cautious handling of mouse cells and tissues is emphasized and the routine ultrastructural examination of such cells highly recommended.

Fatty Acid Composition of Microsomal and Soluble Fractions of Mammary Adenocarcinomas in Mice. GLORIA M. K. RAINES and ALICE S. BENNETT, Ball State University, Muncie, Indiana 47306.——It has been suggested that membrane characteristics associated with carcinomas could be related to an altered molecular structure of lipids in the plasma membrane. The microsomal and soluble fractions of the cell are major sites of *de novo* synthesis and elongation/desaturation of fatty acids. It was the purpose of this study to compare the fatty acid composition of microsomal and soluble fractions isolated from mammary adenocarcinomas with that of normal mammary tissue and to determine if deviations found in the plasma membrane isolated from tumors could be observed at these subcellular levels. Electron micrographs of tumor cells were compared to those of normal. Microsomal and soluble fractions were isolated by differential centrifugation from mammary adenocarcinomas and from normal mammary tissue of Strain A female mice. Activities of nicotinamide adenine dinucleotide, reduced (NADH) dependent cytochrome C reductase and nicotinamide adenine dinucleotide phosphate, reduced (NADPH) dependent cytochrome C reductase in these fractions were determined. The fatty acids were extracted, methylated, and methyl esters identified and quantified using gas liquid chromatography. Polar and nonpolar GLC columns, silver nitrate thin-layer chromatography, hydrogenation, and spiking were used to confirm the identity of some fatty acids. Electron micrographs revealed that the endoplasmic reticulum of neoplastic cells was more discontinuous and fragmented than that of normal cells. The fatty acid composition of the microsomal fraction did not reflect the altered characteristics evident in the plasma membrane. Generally, the fatty acid composition of the microsomal and soluble fractions was similar in tumor and normal tissue, but there was a greater percentage of $C_{24:1}$ and $C_{22:0}$ fatty acids in tumors. An increase in the level of palmitic acid and of long chain fatty acids, as reported in studies on the plasma membrane isolated from tumors, was not evident in either of the microsomal or soluble fractions. There was evidence of greater utilization of NADPH in the reduction of cytochrome C reductase in tumors. This may result in a decreased availability of NADPH for fatty acid synthetase and lipogenesis.

A Study of the Ultrastructural Changes in Two Irradiated Tissues of Differing Radiosensitivities

W. J. ADAM and R. J. VETTER, Department of Bionucleonics
School of Pharmacy and Pharmacal Sciences
Purdue University, West Lafayette, Indiana 47907

Abstract

A micromorphological study of two different tissues was made in which the only experimental variable was inherent tissue radiosensitivity. Mouse hepatocytes and duodenal epithelial cells were exposed to 1350 R of Co-60 gamma radiation. Tissues were collected 24 hours post-irradiation and prepared for electron microscopy. It was found that while changes in nuclear shape and dilation of nuclear envelopes and endoplasmic reticulum were common to both cell types, these changes were much more exaggerated in the duodenal cells. The duodenal cells also showed nuclear alterations and a type of secondary lysosome which were lacking in the hepatocytes. Fatty degeneration appeared solely in the hepatocytes.

Introduction

Accurate ultrastructural characterizations of cells, including irradiated cells, began in the mid 1950's (18). Since then, numerous accounts have described changes in a wide variety of irradiated tissues under just as wide a variety of irradiation conditions. As a result of these studies, it is clear that the nucleus is the focal point of a cell's reaction to ionizing radiation. However, to say that its reaction represents the full story is a gross oversimplification.

There has, as yet, been no study performed in which a radiosensitive cell's reaction has been compared to a radioresistant cell's reaction at the ultrastructural level with the only variable being cell type. The question that this study attempts to answer is: given that the only intended difference between two populations of cells is their radiosensitivity, will one cell type show significantly different micromorphological alterations than the other after irradiation?

Materials and Methods

Conditions of Irradiation

Male mice of the Cox (Swiss) strain weighing 30 to 36 grams were irradiated singly with a U.S. Nuclear 7500 Ci (3-15-66) Co-60 source. An exposure rate of 178 R/min was used to achieve a total exposure of 1355 R. The source was calibrated with the Victoreen R-meter. A total of seven mice were irradiated, and seven were used as controls. Animals were sacrificed by etherization 24 hours after irradiation. Tissues were fixed with glutaraldehyde which had been redistilled from a 25% stock solution in accordance with Fahimi and Drochmans (5).

The primary lobe of the liver and the first centimeter of the duodenum from irradiated and control mice were fixed immediately after sacrifice. The surface of the liver was rinsed with the primary fixative (3% glutaraldehyde in a 0.05 M phosphate buffer, pH 6.8) before being excised. The duodenum was intraluminally perfused with the fixative before being excised. Liver and duodenum were minced and immersed in fixative at room temperature for 60 to 90 min. After primary fixation, the tissues were rinsed three times with a 0.05 M phosphate buffer followed by postfixation for 2 hours in 2% osmium tetroxide in a 0.05 M phosphate buffer, pH 6.8 at room temperature. The tissues were stained *en bloc* in a 2% aqueous uranyl acetate solution overnight at 4°C. This was followed by dehydration in a graded ethanol series and infiltration with a low viscosity plastic (26). Tissues were sectioned with diamond knives on a Sorvall MT-2B ultramicrotome at a thickness of 600 A. The sections were placed on 300 or 400-mesh bare copper grids, stained with lead citrate (23) and examined on a Hitachi HU-11A electron microscope using an accelerating voltage of 50 KV.

Results

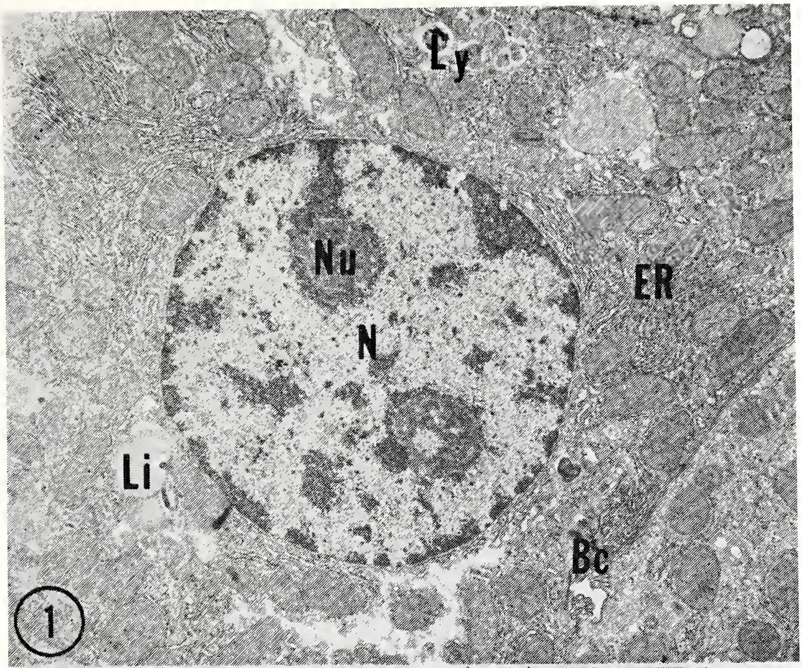
Morphology of Control Tissues

No obvious distortion of the ultrastructure of the mouse hepatocyte was observed in control tissues (Fig. 1). The nuclei were either spherical or near spherical and possessed one or two distinct centrally located nucleoli. The nuclear envelope exhibited no swelling or distension. The heterochromatin appeared as a very thin and consistent border around the inner aspect of the nuclear envelope, avoiding the nuclear pores. Mitochondria were neither swollen nor distorted and cristae appeared linear and unbroken. Rough endoplasmic reticulum (RER) was very abundant and was most often found as rather long, double-membrane units encircling mitochondria or lipid droplets or as a cytoplasmic parallel array of several double-membrane units. The two unit membranes of the RER maintained a strict parallel arrangement. Ribosomes were found either as small, unbound clusters (polyribosomes) or as part of the RER. A small natant population of lipid droplets, primary and secondary lyosomes, and peroxisomes was common.

Control fixations of the duodenal epithelial cells yielded similar morphological results (Fig. 2). Duodenal nuclei often appeared more elipsoidal than hepatocyte nuclei. The RER of the duodenal cells did not maintain the same parallelism between the two unit membranes that was shown in the hepatocytes but, instead, took on a more circular or vesical-like configuration. There was a great deal of variability in the appearance of the mitochondria. They were apparently still unstable after the primary fixation process and, consequently, showed some swelling and dissolution of the matrix. Ribosomes were predominantly attached to the endoplasmic reticulum (ER) or were found free in the cytoplasm as polyribosome clusters. An occasional primary or secondary lysosome was also found. The apical ends of the cells were covered with a dense population of microvilli.

FIGURE 1. *Control hepatocyte. N, nucleus; Nu, nucleolus; ER, endoplasmic reticulum; Bc, bile canal; Li, lipid; Ly, Lysosome; Mag.=3417X.*

FIGURE 2. *Control intestinal epithelial cells. Mv, microvilli; Ly, lysosome; RBC, red blood cell; Jc, junctional complex; Mag.=5576X.*


Ly
Nu
N
ER
Li
Bc
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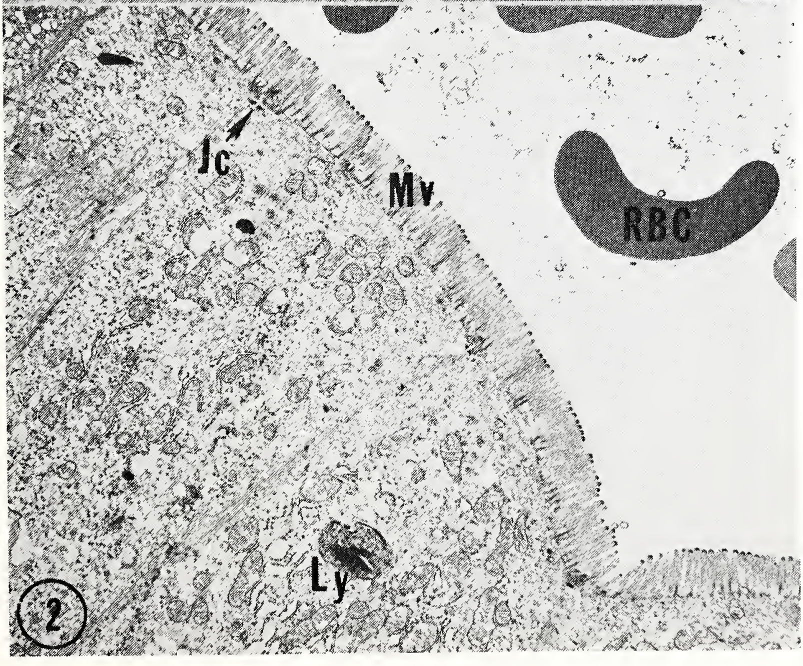

Jc
Mv
RBC
Ly
②

The Irradiated Hepatocyte

One of the more striking features of the irradiated hepatocyte was the appearance of the reticular network (Fig. 3). The cells had ER that was very dilated sometimes to very exaggerated extremes. When this characteristic appeared at all, it was universal throughout the affected cell. The voids caused by this dilation of the ER did not contain any electron dense debris. Along with the dilation of the ER, there occurred a similar dilation of the nuclear envelope which was in some cases quite exaggerated, appearing only between the nuclear pores. Lobing or "blebing" of the nucleus was frequently observed. The nucleus became more or less amorphous in shape, possessing tabs or lobes which extended into the cytoplasm. Changes in shape of the nucleus and ER occurred together in almost every case. The exceptions were a few instances where swelling of the ER occurred without any nuclear alterations. Increased cytolytic activity was evidenced by an increase in size, complexity and number of secondary lysosomes (Fig. 4). These cytolytic bodies often possessed various sizes of lipid droplets, membrane fragments, and osmiophillic plaques and tended to cluster in small groups. Mitochondrial changes were limited to a slight to moderate loss of density of the matrix or a disruption of the internal membrane system (Fig. 5). No alterations were noticed in the distribution of the ribosomes.

The Irradiated Duodenal Epithelial Cell

As with the hepatocyte, the most obvious changes in the duodenal cells involved the nucleus and the endomembrane system. The ER was very vesiculated (Fig. 6), often so extensively that the cytoplasm appeared somewhat frothy. The nuclear envelope took on a swollen or distended character, and the nucleus became amorphous.

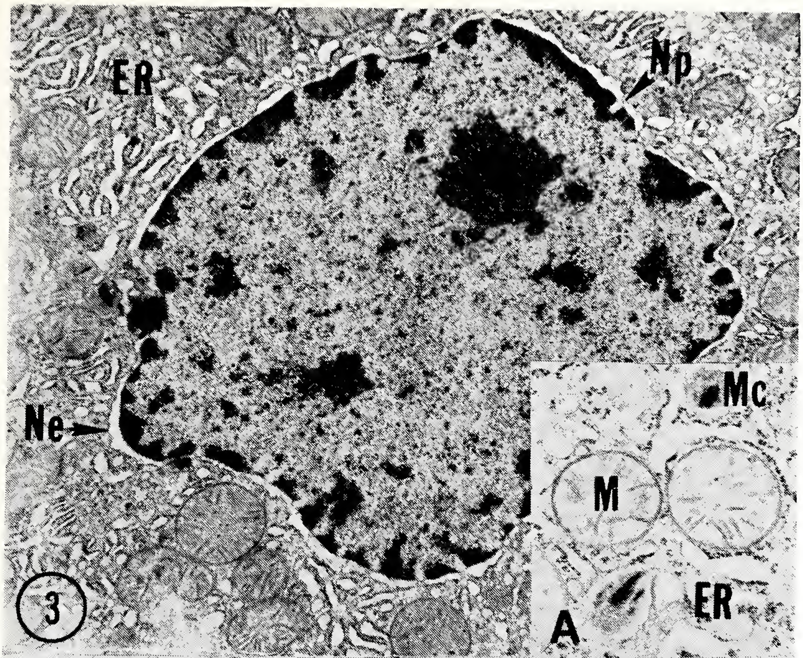
The main difference between the irradiated hepatocyte and the irradiated duodenal epithelial cell was one of degree. While nuclear alterations in the hepatocyte were confined to changes in outline, nuclear changes in duodenal cells were much more elaborate and, on occasion, so extreme as to give the appearance of isolated islands of chromatin, cytoplasmic pockets, or pseudopodia-like extensions of the nucleus (Fig. 7). In some cases, the duodenal nuclear envelopes would swell to the extent of becoming balloon-like. Figure 7 shows one case in which the nuclear envelope had partially dissolved and cytoplasmic and nuclear contents had become mixed. Changes within the nucleus were also more pronounced in the duodenal cells. There were instances of nuclear caps (Fig. 8) and pycnotic nuclei (Fig. 9), neither of which was found in the irradiated hepatocyte.

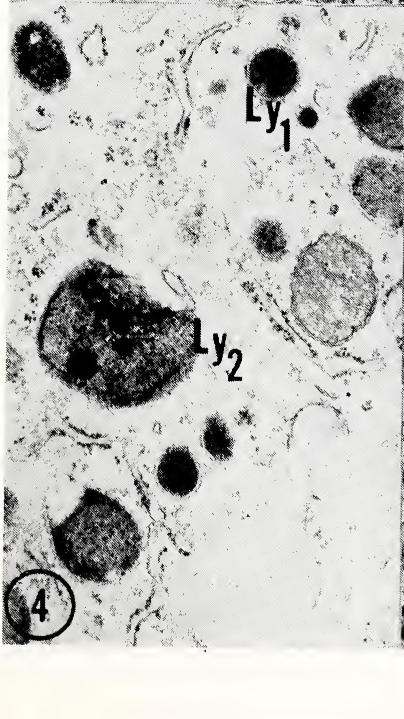
FIGURE 3. *Irradiated hepatocyte. ER, endoplasmic reticulum; Np, nuclear pore; Ne, nuclear envelope; Mag.=5495X.*

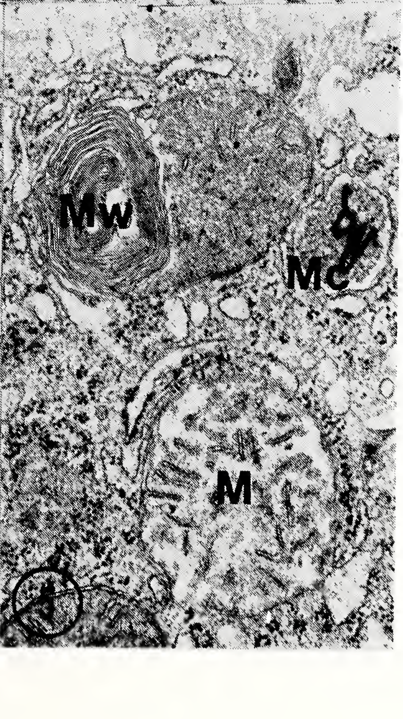
FIGURE 3A. *Irradiated hepatocyte. ER, endoplasmic reticulum; M, mitochondria; Mc, microbody; Mag.=24,074X.*

FIGURE 4. *Lysosome aggregate of irradiated hepatocyte.* Ly_1, *primary lysosome;* Ly_2, *secondary lysosome; Mag.=4689X.*

FIGURE 5. *Mitochondria of irradiated hepatocyte. M, mitochondria with a low density matrix; Mw, membrane whorl; Mc, microbody; Mag.=19,428X.*


ER
Np
Ne
Mc
M
ER
A
3


Ly$_1$
Ly$_2$
4


Mw
Mc
M

The lysosomal systems of the two cell types behaved similarly. The hepatocyte lysosomes rarely became more elaborate than those shown in Fig. 4. However, the duodenal lysosomes were more numerous, considerably larger, and more complex. There was a great heterogeneity of contents within the duodenal lysosomes which included whole areas of cytoplasm, extensive collections of membranes, mylenated figures, lipid droplets of various sizes and densities, and occasionally an entire organelle (Fig. 10). Some of the duodenal lysosomes were considerably larger than their hepatic counterparts and in several instances, occupied approximately one-third of the volume of an epithelial cell. Other variants of the lysosomal system present only in the irradiated duodenal epithelial cell were the multivesicular body, residual bodies, and membrane whorls. As with the irradiated hepatocytes, there was no perceptible change in ribosomal distribution; however, the Golgi complex did exhibit isolated incidences of hypertrophy.

Discussion

Cell Population Kinetics

Unless hepatic cells are stimulated by artificial means, such as partial hepatectomy, they will divide rarely, if at all (19). The duodenal epithelial cells, however, divide very rapidly and are known to be very radiosensitive (16). Like many radiosensitive systems, the intestinal epithelium is a cell renewal system (15). The majority of the epithelium consists of crypt cells which move in a coherent sheet up the villi where they are extruded at the tip (21, 27). The generation time of proliferating crypt cells is about 12 hours.

Light microscope studies have shown that mitotic activity is abolished in stem cells shortly after a supralethal dose of x-rays (27). X-irradiation with 1 krad leads to depletion of the intestinal epithelium, "anenterocytosis", through aplasia combined with continued loss of mature cells (16). Movement of the entire epithelial sheet and extrusion of cells from the tips of the villi seems to be blocked for about 0.5 day after irradiation (10). It would seem unlikely then, that ultrastructural changes found in this study were due to any magnification effects resulting from differences in cell cycle times, since mitosis is blocked by the magnitude of exposure that was used.

Nuclear Alterations

In both the hepatocyte and the duodenal epithelial cells, nuclear alterations of two main types were found. First, as in several other studies, the nuclear envelope exhibited slight to severe swelling (2,6,7, 11,25). The severity of this alteration was always greater in the duodenal cells. A second alteration which had taken place in the nuclei

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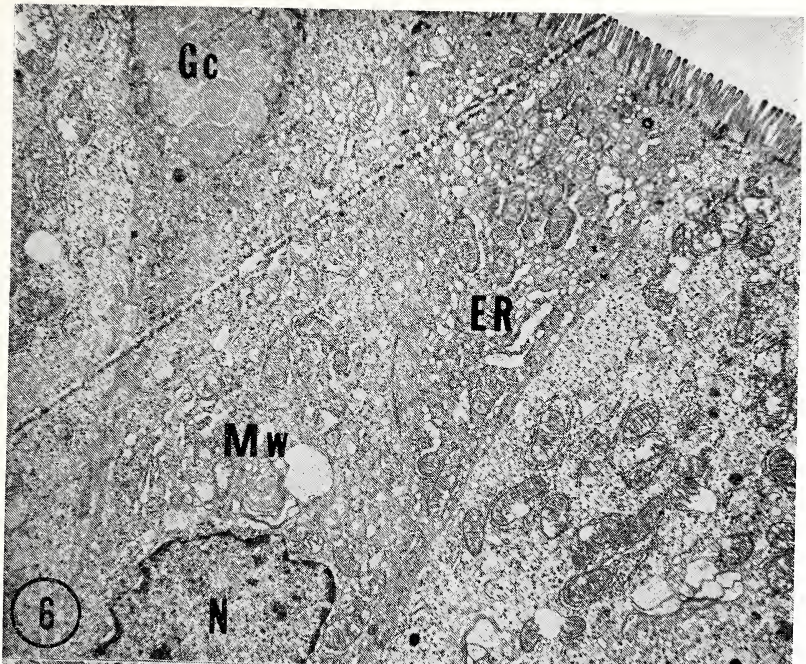
FIGURE 6. *Irradiated intestinal epithelium. ER, endoplasmic reticulum (dilated); Gc, goblet cell; N, nucleus; Mw, membrane whorl; Mag.=2728X.*

FIGURE 7. *Transverse section of intestinal epithelial cell. Nuclear contents have partially spilled into cytoplasm (arrow); Mag.=4986X.*

FIGURE 7A. *Extremely lobed nucleus of irradiated intestinal epithelial cell. Cytoplasmic packet (arrow); Ch, isolated island of chromatin; Mag.=1740X.*


Gc
ER
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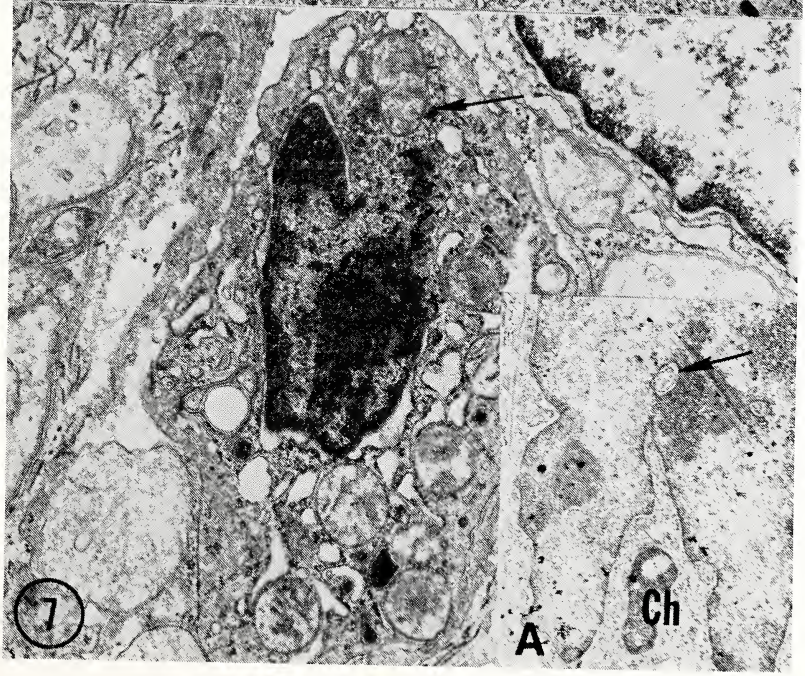
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A
Ch

of both cell types was a change in the outline of the nucleus. This "blebing" or lobing was, again, more exaggerated in the duodenal cells than in the hepatocytes. Both swelling of the nuclear envelope and nuclear blebing are not uncommon to irradiated tissues (2,3,11). Within 1 hour after a 3-krad dose, irregularly shaped nuclei were found to be commonplace in the epithelium of the irradiated intestine along with an increase in the size of the nuclei (20). Nuclear envelopes of irradiated epithelial duodenal cells were "tremendously swollen" as early as 2 hours after an exposure of 1350 R (10). Irregularities in nuclear shape were found as early as 90 min after a 1350 R exposure along with "chromatin-like areas" dispersed within the cytoplasm or bulging from the nuclear surface (13). It is interesting to note that the irregular shape of the nucleus after irradiation is also observed in transformed cells.

Endoplasmic Reticulum

Distention and dilation of the ER was also a very common characteristic of both cell types used. Dilated ER is not uncommon in irradiated tissue (1,6,11,14). In hepatic parenchymal cells ER was observed in varying degrees of dilation at all post irradiation intervals greater than 4 hours after a 3-krad dose of Co-60 gamma rays (8) and was found as early as 2 hours post irradiation in the epithelium of the duodenal crypts in x-irradiated mice (10). Along with the distention and dilation of the ER, an apparent loss of ribosomes was observed in several studies (13,17,20,12). No obvious reduction in the number of ribosomes was found in either of the tissues used here.

Lysosomes

One of the more dramatic changes observed in this study was the change in the lysosomal component of irradiated cells. There was an increase in the number and internal complexity of these organelles in both cell types along with an increase in the number of primary and secondary lysosomes. However, in duodenal cells the size and complexity of secondary lysosomes was far greater than in hepatocytes.

Changes in the lysosome population of hepatic parenchymal cells have been observed as early as 2 min post irradiation (8). These changes were referred to as "membranous annuli" enclosing a variety of cytoplasmic components. Such structures are identical, by definition, to autophagosomes. Rene et al. (22) found a simultaneous increase in both the number of lysosomes and the activity of acid phosphatase in hepatocytes of rats 2 hours after a 2-krad dose. Changes in the lysosomal

FIGURE 8. *Irradiated intestinal epithelial cell. Nucleolar cap, Nc; Mag.=2250X.*

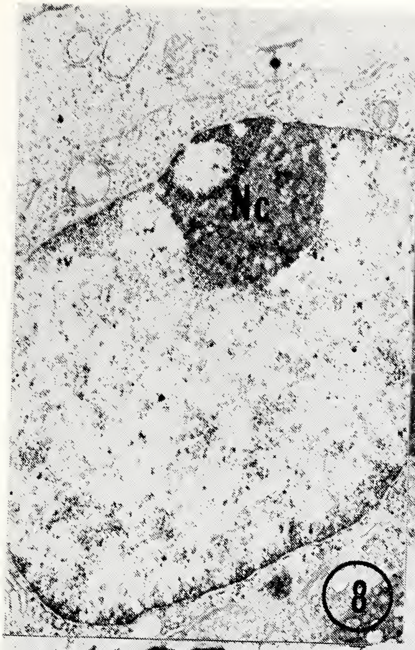
FIGURE 9. *Pycnotic nucleus, irradiated intestinal epithelial cell. Mag.=2931X.*

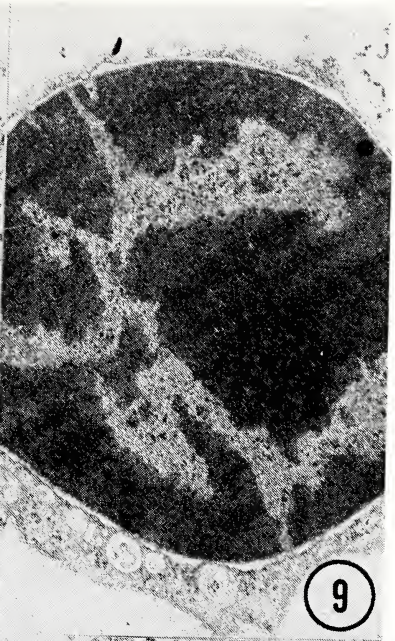
FIGURE 10. *Large cytolysosome in irradiated intestinal epithelial cell. Mv, microvilli; Cy, cytolysosome; Mag.=3960X.*

FIGURE 10A. *Irradiated intestinal epithelial cell, cytolysosome with osmiophilic plaque, Op; Mag.=20,833X.*

FIGURE 10B. *Irradiated intestinal epithelial cell. Mv, multivessicular body; Mag.=11,505X.*

FIGURE 10C. *Irradiated intestinal epithelial cell, cytolysosome. Me, membranes; Li, lipid droplet; Cy, cytoplasmic inclusion; Mag.=10,500X.*


Nc
8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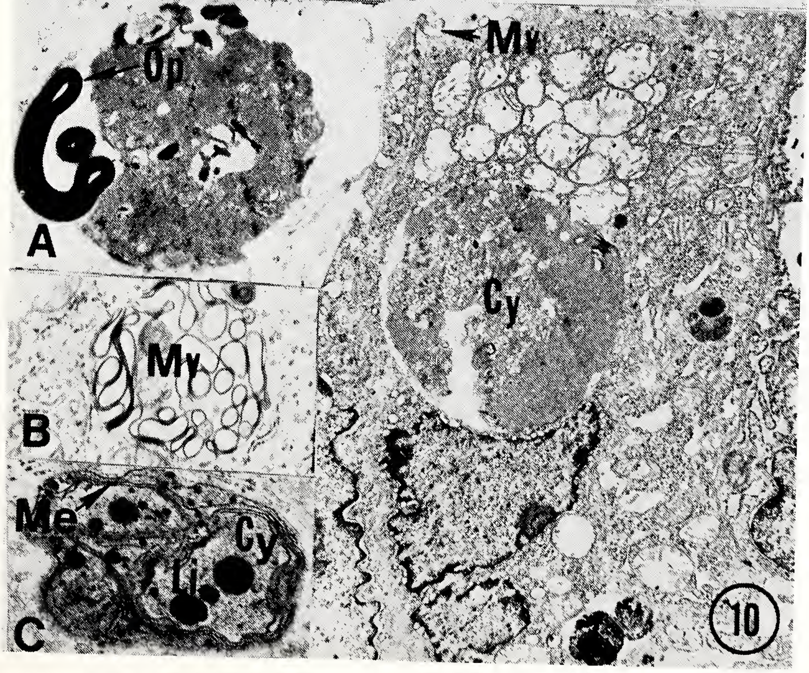
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10

content of irradiated duodenal epithelial cells is considerably more elaborate than in irradiated hepatocytes. An increase in the number of multivesicular and dense bodies was observed in these cells as early as 90 min after a 1350-rad dose of x-rays (9,10,12,13). The number of cytolysosomes was also increased beginning at 3 hours post irradiation. These cytolysosomes were found to contain mitochondria, ER ribosomes and nuclear fragments.

Other Cellular Components

In the irradiated hepatocyte, fatty degeneration has been demonstrated (8,19). In this study, it appeared as the deposition of numerous clear vacuoles from which the lipid component was leached out during processing. Hendee and Alders (8) found these lipid vacuoles as early as 4 hours after exposure of rats to 3 or 16 krad.

No obvious changes in the morphology of the Golgi complex was found in this study. Hugon et al. (10) reported a reduction of the Golgi area to a few cysternae. This finding was predominant at 2 hours post irradiation. It is conceivable that what was seen in Hugon's study may have been the result of unusual sectional geometry, or what may have been seen was small clusters of smooth ER.

The significance of the present study lies in the experimental design. If one wishes to consult the literature and compare ultrastructural characteristics of two different irradiated tissue types, one would undoubtedly find the two particular tissues of interest. However, the exposure, exposure rate, the post irradiation time at which the tissue was collected and the species from which the tissue came would all very probably be at variance with one another. In this study the only variables are those inherent in the two different tissues. Even more significant are the differences seen when all the above-mentioned variables are kept constant, for it is these differences that are the net result of how two different cell types cope with exposure to ionizing radiation.

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The Oligosaccharides of Serum Lipoproteins: A Brief Review and Localization of an Apoprotein Sialyl Transferase in Golgi Apparatus and Partial Purification of the Enzyme[1]

MARK EPPLER[2] and D. JAMES MORRÉ[3]
Department of Biological Sciences
Purdue University, West Lafayette, Indiana 47907

Abstract

Many of the apoprotein subunits of the serum lipoproteins of humans and other species contain covalently-bound carbohydrates in the form of oligosaccharides attached to specific amino acid residues. Glycosylation of the apoproteins occurs in specific cell organelles organized into two linear routes of synthesis and secretion. Early glycosylation may determine which route is followed or glycosylation may vary depending on which route is followed. Since bound oligosaccharides appear to be involved in recognition by both hepatic and extrahepatic receptors, the synthesis-secretion route may ultimately control the behavior of lipoproteins in blood. Both abnormal recognition and abnormal glycosylation of serum lipoproteins are encountered with atherosclerotic and/or dislipoproteinemic patients. An apoprotein sialyltransferase which terminally glycosylates circulating lipoproteins is localized in Golgi apparatus, where it is strongly bound to the membranes. This activity of the Golgi apparatus has been solubilized using detergents and purified 150-fold.

Serum lipoproteins may be divided into three classes based on flotation density in the ultracentrifuge (3). These are very low density lipoproteins (VLDL)($d<1.006$), low density lipoproteins (LDL) ($d = 1.006$-1.063) and high density lipoproteins (HDL)($d = 1.063$-1.210). Lipoproteins of all species studied, including man, have great similarity in the protein subunits (apoproteins) of these circulating lipoproteins. VLDL contains apoproteins B, C-1, C-2, and C-3 in addition to an arginine-rich protein. LDL contains primarily apoprotein B and sometimes the arginine-rich protein. HDL contains A-1, A-2 and the arginine-rich and C peptides. Many of these peptides contain covalently-bound carbohydrate (Table 1) so that these circulating lipoproteins are actually glycolipoproteins.

Oligosaccharides of glycoproteins in general have been implicated as controlling factors in their secretion. Eylar (4) observed that all of a group of secreted proteins were glycoproteins and that most intracellular proteins were not. He interpreted this as evidence for a glycosylation-dependency of glycoprotein secretion. Knopf et al. (10) found that addition of fucose to light chains of immunoglobulin secreted by murine myeloma cells only occurs immediately before their secretion as if the terminal fucose of the oligosaccharides allowed the last step in secretion to occur. Finally, Pottenger et al. (18) demonstrated that apoproteins which accumulate in rough endoplasmic reticulum vesicles of orotic acid-induced fatty livers were deficient in N-acetylglucosamine, galactose, and sialic acid.

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[1] Supported in part by a grant from the American Heart Association.

[2] Predoctoral Fellow of the American Heart Association, Indiana Affiliate.

[3] Appointed jointly with the Department of Medicinal Chemistry.

TABLE 1. *Comparison of the carbohydrate composition of human and rat apolipoproteins.*

Apoprotein	Carbohydrate Composition			
	Human	Ref.	Rat	Ref.
B	Man, GalNAc, Gal, NAN	26		
A-I	Hexose, hexosamine	20		
C-3	GalNAc, Gal, NAN	1	GalNAc, NAN	5
Arg-rich	Binds to ConA-sepharose	24	Man, Gal, Glu, NAN N-acetylhexosamine	18

Abbreviations: Gal = Galactose; GalNAc = N-acetylgalactosamine; Glu = Glucose; Man = Mannose; NAN = N-acetylneuraminic acid (sialic acid).

Contrary to Eylar's (4) expectations, more recent studies have shown that human serum, bovine milk, and bovine pancreatic juice, all secreted fluids, contain from 40 to 95% non-glycosylated proteins; non-glycosylated collagen is also secreted in certain disease states (23). Pottenger et al. (18) prefer the interpretation that lipoproteins were abnormally glycosylated because they had not passed through Golgi apparatus where the terminal glycosyl transferases are concentrated. A reasonable model of synthesis-secretion of glycoproteins has been constructed which may explain these seemingly disparate observations (16). Lipoproteins may exit the cell via secretory vesicles derived from either the Golgi apparatus or, more directly, via vesicles derived from smooth endoplasmic reticulum (SER). Presumably, proteins secreted by SER vesicles are less glycosylated than those secreted by Golgi apparatus-derived vesicles, paralleling the subcellular distribution of the glycosyl transferases that catalyze sugar additions. Sugars are added to glycoproteins in specific sequence, the product of one reaction becoming the substrate of the next transferase in the pathway (8). Also certain glycosylations near the core region of the glycoprotein oligosaccharide can preclude the possibility of more terminal glycosylations (8). Non-glycosylated collagen and other non-glycosylated serum proteins might be secreted by the SER route, thus bypassing certain terminal glycosylation steps. Glycosyl transferases catalyzing additions of mannose and internal N-acetylglucosamines are found in endoplasmic reticulum as well as Golgi apparatus (22). The observed increased levels of internal sugars such as mannose in lipoproteins of orotic acid-induced fatty livers may reflect such activities. That alterations of normal intracellular flow of lipoproteins can occur has been demonstrated by Werderitsh et al. (27). Hyperlipoproteinemic rabbits had disoriented Golgi apparatus with large accumulations of lipid in smooth endoplasmic reticulum in the apical cytoplasm.

The potential importance of terminal sialic acids in determining the clearance of glycoproteins from blood has been shown by Morrell et al. (14) in that removal of sialic acid from a variety of glycoproteins caused their rapid accumulation in the liver through interactions with a specific receptor (7). Although the role of sialic acid in determining lipoprotein clearance is not certain, oligosaccharides in general are involved in a wide range of effector-receptor interactions (2). Therefore it is to be expected that the secretory route will profoundly influence the behavior of secreted lipoproteins in the circulation. The abnormal occurrence of lipoproteins in arterial intima during atherogenesis (25) and some forms of hyperlipoproteinemia, may be a reflection of altered lipoprotein-receptor interactions.

An understanding of the characteristics of the glycosyl transferases plus clarification of the mechanisms of their incorporation into a specific biosynthesis-secretory pathway will contribute much toward completing the conceptual framework of lipoprotein synthesis and assembly. Munro et al. (17) have shown an apolipoprotein sialyltransferase to be concentrated 45-fold in rat liver Golgi apparatus. Yet, no work has been directed toward isolation, purification and detailed characterization of these enzymes.

As part of a study to isolate and characterize the glycosyl transferases of lipoprotein glycosylation, Golgi apparatus were isolated from rat liver as described (15). The isolated Golgi apparatus were treated with ultrasound for 1 minute (Branson sonifier, micro tip, amplitude setting of 1) in 0.05 M KCl containing 0.1 M Tris-maleate, pH 6.6 and 14 mM 2-mercaptoethanol. Membranes were collected by centrifugation (85,000 X g for 1 hr), resuspended in the same buffer and Triton X-100 was added to 0.6% at a protein concentration of about 1 mg/ml of final solution. This solution was treated with ultrasound for 1 min, amplitude setting of 1. Following a 3.5 hr incubation at 4°, insoluble residue was removed by centrifugation (1 hr, 100,000 X g). This treatment completely solubilized the sialyltransferase in a form satisfactory for further purification and characterization. The recovery was 68% of that in the original Golgi apparatus.

To assay the sialyltransferase, VLDL were isolated from whole rat blood by the method of Koga et al. (9), delipidated according to Scanu et al. (21) and desialated using neuraminidase from *Clostridium perifringens* (Sigma Chemical Co., St. Louis, 0.14 enzyme units/mg protein) (28). Incubations were for 10-20 min at 37°. The reaction mixture contained, in a final volume of 0.05 ml, the following: 0.15 M sodium cacodylate, 0.5% Triton X-100, 0.5% Triton CF-54, 10 mM $MgCl_2$, 14 mM 2-mercaptoethanol, 18 nmoles ^{14}C-CMP-sialic acid (6.6 mCi/mmole), 7-10 μg asialoVLDL, and 15-60 μg enzyme protein, final pH 6.4. The reaction was terminated by addition of chloroform-methanol (2:1, by volume) to precipitate protein and extract lipids. The precipitated protein was washed twice each with acetone-water (1:1, by volume) and water, and radioactivity was determined by liquid scintillation counting. Enzyme specific activities were calculated from the counts per min of radioactive sialic acid transferred to the desialylated VLDL. Proteins were estimated by the Lowry et al. (13) method following extraction to remove excess Triton X-100 (7).

The sialyltransferase of VLDL sialylation was concentrated 79-fold in Golgi apparatus relative to the starting homogenate (Table 2). The enzyme was tightly bound to the membrane; treatment with KCl to release secretory and extrinsic membrane proteins resulted in a further purification of the sialyltransferase of 1.5. The final purification of the

TABLE 2. *Purification of CMP-NAN: desialylated apoVLDL sialyl transferase from Golgi apparatus of rat liver.*

Enzyme Source	Specific Activity (nanomoles sialic acid/hr/mg protein)	Relative Specific Activity	Total Activity (nanomoles sialic acid/hr/10 g rat liver)
Total Homogenate	0.32	1	390
Golgi Apparatus[a]	25	79	150
Golgi Apparatus Membranes			
Low Salt Extracted[b]	38	121	105
Triton X-100 Extract[c]	47	150	100

[a] Recovery of Golgi apparatus determined from other criteria (15) was about 40%. This means that (150 X 100/40)/390 = 96% of the activity was probably Golgi apparatus-associated in the original homogenate.

[b] Low salt extraction solubilized 150 − 105/150 X 100 = 30% of the activity. The remainder was associated with the Golgi apparatus membranes.

[c] Triton X-100 solubilized 100/105 X 100 = 96% of the activity remaining with the low salt extracted membranes.

Triton X-100 solubulized enzyme was 150-fold. This partially purified sialyltransferase had an absolute requirement for detergent or lipids.

Recent findings from several laboratories implicate a disfunction in sialyltransferase in atherogenesis. Lee and Breckenridge (11) report lower quantities of both mannose and sialic acid in apoproteins from type II hyperlipoproteinemic subjects while galactose and N-acetylglucosamine were unchanged. In a second paper, these authors could find no differences in carbohydrate chains of individually isolated glycopeptides of LDL, suggesting that the lesion was the result of change in proportion of sialylated glycopeptides, i.e., due to decreased amount of glycopeptides of similar composition to those found in normal subjects (12). This contrasts with studies of the abnormal lipoproteins in abetalipoproteinemia, where an oversialylated form of HDL predominates (19). A recent report (6) provides evidence that a structurally defective LDL may not bind properly to surface receptors. Cholesterol synthesis in leukocytes from the affected subjects was not suppressed by the subject's own LDLs but was suppressed by LDLs from control subjects. Conversely, LDLs from the diseased subjects failed to suppress cholesterol synthesis in control leukocytes. Thus the complex carbohydrate array of the oligosaccharide chains of circulating lipoproteins may provide surface characteristics that are important to recognition processes. Knowledge of how sialyltransferases of the Golgi apparatus and the operation of alternate secretory routes interact to generate specific carbohydrate sequences may be important to understanding and treatment of various forms of hyperlipoproteinemia and atherogenesis.

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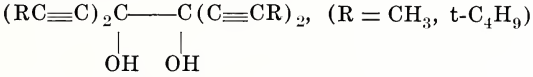
CHEMISTRY

Chairman: JOHN H. MEISER, Department of Chemistry
Ball State University, Muncie, Indiana 47306

Chairman-Elect: PANG-FAI MA, Department of Chemistry
Ball State University, Muncie, Indiana 47306

ABSTRACTS

Numerical Coding as a Teaching Aid for Infrared Spectroscopy. ROBERT E. VAN ATTA, Department of Chemistry, Ball State University, Muncie, Indiana 47306.——A numerical coding system for describing, filing, and retrieving infrared spectra is presented which permits systematic organization of a spectrum library for instructional use. The system, which may also be used for rapid coding of commercially available spectra, involves selection of principal absorption bands at three levels of intensity in characteristic spectral regions. The nature of the spectrum may be deduced from the numerical code, thus simplifying retrieval for qualitative comparisons. Retrieval may be accomplished via index card, rolodex systems, punched card, or computerization.

Snythesis and Reactions of Tetraethynylethylene Glycols. STEPHEN M. KELNER and KENNETH G. MIGLIORESE, Department of Chemistry, Indiana University Northwest, Gary, Indiana 46408.——In an attempt to devise an unambiguous synthetic route to tetraethynylethylenes, compounds of the general type  $(RC\equiv C)_2\underset{OH}{\underset{|}{C}}-\underset{OH}{\underset{|}{C}}(C\equiv CR)_2$, ($R = CH_3$, t-$C_4H_9$) were prepared by reacting the appropriate acetylenic Grignard reagent with diethyl oxalate. To date, all attempts to convert these tetraethynyl glycols to the corresponding tetraethynylethylenes has been unsuccessful. The glycols themselves do, however, exhibit some interesting chemistry which will be reported.

Chemical Modification of Human Prostatic Acid Phosphatase. JOHN J. MCTIGUE and ROBERT L. VAN ETTEN, Department of Chemistry, Purdue University, West Lafayette, Indiana 47907.——Human prostatic acid phosphatase (HPAP) catalyzes the hydrolysis of the monoanionic form of a wide range of phosphomonoesters. We considered it likely that a positively charged group at the active center of HPAP accounted for this specificity for the monoanionic form of the substrate. Since no metal ion has been found to be associated with this enzyme, we examined the possibility that a positively-charged residue such as lysine or arginine was essential for the binding of substrate. Experiments with trinitrobenzenesulfonic acid and pyridoxal 5-phosphate have excluded an active-site lysyl residue from the binding function, while treatment of the enzyme with either of the arginine-specific modifiers 2,3-butanedione or 1,2-cyclohexanedione in borate buffer at pH 8.1 leads to the loss of activity. The rate of inactivation is decreased markedly in the presence of the competitive inhibitors L-(+)-tartrate or inorganic phosphate but not in the presence of the non-inhibitor D-(–)-tartrate.

Several reports have indicated that a phosphoenzyme intermediate is involved in the mechanism of acid phosphatases. To ascertain the identity of the amino acid residue involved in the formation of this intermediate, further chemical modification studies were undertaken. Reaction of HPAP with diethyl pyrocarbonate in succinate buffer at pH 6.0 leads to inactivation of the enzyme. Under these conditions histidine and lysine residues are modified. In the presence of competitive inhibitors the rate of inactivation is decreased. These results suggest an essential role for arginyl and histidyl residues in the mechanism of HPAP, probably with arginine in a binding site for the negatively charged phosphate group of the substrate and with histidine acting as a nucleophile in the catalytic mechanism.

A Study of the Interconversion of Human Adenosine Deaminases in Cancerous and Normal Tissues. J. ZACHARY, P. F. MA, and J. M. COERS, Department of Chemistry, Ball State University, Muncie, Indiana 47306.——Two different molecular forms of adenosine deaminase have been found in various human tissues: The high molecular weight enzyme (A form) and the low molecular weight enzyme (C form). The two forms of the enzyme are present in various proportions in different tissues and are interconvertible. There is an indication that a conversion factor is involved in this interconversion. To study this interconversion phenomena in cancerous and normal tissues, a series of incubation experiments have been attempted. A purified tissue extract containing only one of the isozymes is incubated separately with two crude tissue extracts, one normal and one cancerous. The samples, along with the appropriate controls, are subjected to thin-layer gel filtration to separate and identify the isozymes. Isozyme location on the plate is detected by measuring the enzyme activity spectrophotometrically, in eluted fractions.

Environmental Co-carcinogens. STEPHEN R. WILSON, Department of Chemistry, Indiana University, Bloomington, Indiana 47401.——Phorbol esters, the most potent co-carcinogens known, have been isolated from a wide variety of plant sources. Co-carcinogens such as phorbol esters lower the threshold response to carcinogens at 10^{-9} molar concentrations. Since exposure of man to environmental chemical contaminants with carcinogenic potential usually involves frequent or continuous contact with minute quantities of these compounds, co-carcinogens play a decisive role in determining the carcinogenic potency of a mixture. The importance of the concentration of the carcinogen may be relatively minor even though its presence in minute amounts is obligatory. The theory of carcinogenesis and some aspects of the chemistry of phorbol will be discussed.

Isomeric 2-Substituted-1,3,2-diazaphosphorinanes. J. A. MOSBO, Department of Chemistry, Ball State University, Muncie, Indiana 47306.——Isomeric 2-methoxy- *(1)* and 2-dimethylamino-1,3,4-trimethyl-1,3,2-diazaphosphorinanes *(2)* have been prepared and their equilibrium concentrations determined. The distributions of 56:44 for *1* and 60:40 for *2* indicate substantially different behavior between these and the dioxa analogues. Although phosphorus stereochemistries and *cis-trans* geometries could not be identified unambiguously, ^{31}P chemical shifts and infrared phosphoryl stretching frequency data for *1* and *2* and their 2-oxo derivatives led to the speculative assignments of the more abundant isomer of *1* being *cis* and that of *2* being *trans.*

Organonitrile Complexes of Platinum. DAVID A. BLINN and BRUCE N. STORHOFF, Department of Chemistry, Ball State University, Muncie, Indiana 47306.——2-Cyanoethyldiphenylphosphine, 2-cyanocyclopentyldiphenylphosphine, and 2-cyanocyclohexyldiphenylphosphine (L) react with 1,5-$C_8H_{12}Pt(CH_3)_2$ and 1,5-$C_8H_{12}Pt(CH_3)Cl$ to displace the cyclooctadiene and yield monomeric complexes of the stoichiometries $L_2Pt(CH_3)_2$ and $L_2Pt(CH_3)Cl$. Spectroscopic evidence strongly suggests that in these complexes the cyanophosphine ligands function as monodentate phosphines.

Reactions of the $L_2Pt(CH_3)Cl$ complexes with $AgBF_4$ or $AgPF_6$ in acetone yield immediate precipitates along with colorless complexes of the stoichiometry $[L_2PtCH_3]_n{}^{n+}$. Spectroscopic evidence suggests that in these complexes one of the ligands functions as a monodentate phosphine while the other serves as a bridging group. One of the nitrile groups in each of these cationic complexes is particularly reactive and is readily attacked by alcohols.

The Synthesis and Some Reactions of 1-Bromo-2(phenylethenyl)benzene. BRUCE N. STORHOFF, Department of Chemistry, Ball State University, Muncie, Indiana 47306.——The title compound has been synthesized in good yield from readily available starting materials by utilizing Wittig reagents. The synthetic procedures are based on the reaction of benzaldehyde with a Wittig reagent prepared from o-bromobenzyl bromide and either triphenylphosphine or triethylphosphite, which yields the corresponding stilbene. The desired product is obtained by dehydrohalogenation of the previously brominated stilbene.

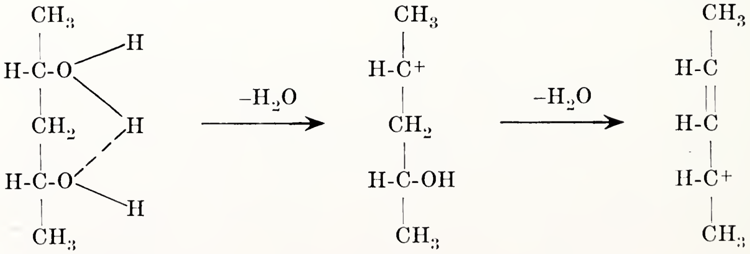
The bromine in the title compound is metalated by n-butyllithium at low temperature. Some reactions of the metalated product were investigated.

Chemical Education for Artists, Philosophers, Economists, and Politicians. TERRY L. KRUGER and FREDERICK K. AULT, Department of Chemistry, Ball State University, Muncie, Indiana 47306.——Trends in chemical education for nonscience majors from Sputnik to the present were discussed. During the past ten years, two widely different chemical education philosophies have evolved and now seem to dominate courses designed for nonscience majors. The two philosophies differ primarily on the issue of principles and relevance versus relevance without substance. The emphasis on relevance can result in a serious neglect of fundamental chemical concepts. The authors expressed a preference for course organization that makes basic chemical concepts the heart of the course with excursions into relevance at a depth to illustrate the application of concepts.

Understanding the pedagogical issues involved in course design requires consideration of psychological, philosophical, and economic factors which affect our lives. The alienation of modern man from his technological surroundings has been enhanced through misunderstanding of scientific concepts and as a result of advertising promises on products which fail to deliver as claimed. The modern citizen reacts predictably when faced with devices of limited lifetime and utility while experiencing decreasing economic power. The reaction has been an expression of resentment and hatred toward the scientific-technological community.

The authors proposed to offer relevance in the nonscience major course through a nonmathematical treatment of basic chemical concepts using many examples illustrating the utility of the concepts. Concepts treated in the course include elemental organization, structure and function, temperature and disorder, stoichiometry related to resource utilization, properties of solutions, and thermodynamics.

Stereoisomeric Studies in the Gas Phase on the MIKES. T. L. KRUGER and J. A. MOSBO, Department of Chemistry, Ball State University, Muncie, Indiana 47306, and R. G. COOKS, Department of Chemistry, Purdue University, West Lafayette, Indiana 47907.——Mass Analyzed Ion Kinetic Energy Spectrometry (MIKES) has been developed for studying the behavior of Ions in the gas phase. Extension of the technique has been made to organic analysis and to the determination of gas phase equilibrium constants. Isomers of the functional group position type have shown large differences in gas phase ion fragmentations (Anal. Letters, 1976). We will discuss the application of the method to the determination of the stereochemistry of ions in the gas phase. The systems studied thus far are the 2,4-disubstituted pentanes, where the substituent is hydroxy-, amino-, and N-methylamino-. The decompositions (metastable) of the dihydroxy are loss of one and two water molecules. The *meso* compound loses the second water with three times the frequency in comparison with the first (water loss) and the d,l pair. The initial conclusion is that MIKES will prove useful in stereochemical studies in at least some cases.



(1)

meso

The Reaction of Methyl Vinyl Ether with Chlorine. T. C. SCHWAN and CURTIS R. WILLE, Department of Chemistry, Valparaiso University, Valparaiso, Indiana 46383.——The reaction of chlorine with methyl vinyl ether would be expected to be a simple and straightforward addition. However, in addition to the expected product, 1,2-dichloromethoxyethane, appreciable quantities of 2-chloro-1-methoxyethene are produced as well as minor amounts of at least eleven by-products. A few of these by-products, acetaldehyde, methyl acetate, 1,1-dimethoxyethane, 1,1-dimethoxy-2-chloroethane and 3-chloropropanal have been identified tentatively by GC-MS analysis. Mechanisms by which these minor by-products form remain to be elucidated; they should prove interesting.

A Study of an Oscillating Chemical Reaction. PHILIP L. BURKHOLDER, 143 Littleton St., West Lafayette, Indiana and JAMES T. STREATOR, Department of Chemistry, Manchester College.——An acidic solution of potassium iodate, malonic acid, hydrogen peroxide, and manganese II sulfate will oscillate at 25° as the system approaches an equilibrium state. The period of the oscillations can be varied over a considerable range by varying the concentrations of the reactants. The presence of an iodine intermediate can be made quite visible by the addition of starch. A study of this reaction was made to devise procedures for measuring temperature and spectral changes that occur during the oscillations. These procedures were used in an attempt to unravel some of the kinetic and thermodynamic properties of the system.

The Photolytic Rearrangement of 1-Adamantyl Azide. GRANT KRAFT and A. GILBERT COOK, Department of Chemistry, Valparaiso University, Valparaiso, Indiana 46383.——The photolytic rearrangement of 1-adamantyl azide has been studied in several solvent systems. The photolysis of the azide in methanol, ethanol and isopropanol produced 1-methoxy-2-azahomoadamantane, 1-ethoxy-2-azahomoadamantane and 1-isopropoxy-2-azahomoadamantane, respectively, in yields of 90-95%. Photolysis of the azide in cyclohexane and *n*-heptane gave a dimeric compound, and photolysis in furan solvent yielded primarily the dimer with some furan adduct. Several possible mechanisms for the rearrangements are discussed.

Inhibitor Effects of Three Adenosine Analogs on ADP Induced Platelet Aggregation

Barth H. Ragatz and Panayotis G. Iatridis
Northwest Center for Medical Education
Indiana University School of Medicine, Gary, Indiana 46408

Abstract

Adenosine and certain C-2 analogs are known to be potent *in vitro* inhibitors of platelet aggregation. Three synthetic nucleosides have been investigated and compared as inhibitors to adenosine. One of these three compounds, 1, N^6–ethenoadenosine (E–Ad) contains an additional ring fused to the adenine nucleus and is a poor inhibitor of adenosine 5–diphosphate (ADP) induced platlet aggregation even though the corresponding ADP analog is a stimulator of platelet aggregation. Two of these compounds 2′–0–methyladenosine (MeAd) and adenine arabinoside (A•Ara) are pentose modifications at position C–2′ and are also poor inhibitors of ADP induced platelet aggregation although A•Ara exhibits a time dependent improvement as an inhibitor. The effects of these compounds emphasize both the importance of structural integrity of the ribofuranosyl ring in adenosine and of the purine nucleus as the upper limit for size of a fused ring system in maintaining adenosine-like inhibitor functionality.

Introduction

Born (4) observed that adenosine is a potent inhibitor of ADP induced platelet aggregation *in vitro.* Mills *et al.* (8) reviewed the effects of various purine modified adenosine analogs and reported several of them with substituents at position C-2 to be even more potent inhibitors of ADP induced platelet aggregation than adenosine. Mester and Mester (7) found 2′-deoxyadenosine to be a weak inhibitor, and the 2′,3′-dialdehyde derived from adenosine by periodate cleavage to be devoid of inhibitor effect on ADP induced platelet aggregation.

The present investigation has been undertaken to study the correlation of the purine nucleoside chemical structure to inhibitor potency on ADP induced platelet aggregation.

Materials and Methods

Freshly collected whole blood from normal human subjects of both sexes was rapidly mixed with one-tenth volume of 3.2% sodium citrate. Blood donors were free of any medication for at least ten previous days. Platelet-rich plasma (PRP) was prepared by differential centrifugation (3) and platelet count (5) was adjusted to approximately $400{,}000/mm^3$ by saline dilution. All nucleoside compounds used were obtained from P-L Biochemicals, Inc., Milwaukee, Wisconsin, and were dissolved in 0.155 *M* sodium chloride and adjusted to pH 7.0. The two compounds modified in the pentose moiety permit evaluation of the effects of adding a bulky substituent at position C-2′ in 2′-0-methyladenosine (MeAd) or of epimerization at this asymmetric center is adenine arabinoside (A•Ara). The purine modified compound, 1, N^6-ethenoadenosine (E-Ad) contains an additional fused heterocyclic ring which alters electronic charge distribution and hydrogen bonding potentials at nitrogen atoms N 1 and amino N^6. Platelet aggregation was studied by the turbidimetric method of Born (2). Samples of PRP (0.5 ml.) were preincubated either with isotonic sodium chloride solution (0.05 ml.) or with test compound (0.05 ml.) for 30 seconds in the Payton Aggregometer and then stimulated with ADP (0.05 ml.) at a fixed concentration. In another series of experiments, 0.5 ml. PRP samples were treated with 0.05 ml. isotonic NaCl, followed by either 0.05 ml isotonic NaCl or compound after 30 seconds and by a fixed dose of ADP (0.05 ml.) after 5 minutes. Results were obtained using PRP from at least three donors for each compound and relative inhibitor potency was compared to adenosine over the same concentration interval.

Results

None of the three compounds examined (E-Ad, MeAd, A•Ara) showed any tendency to induce platelet aggregation when incubated alone with PRP and even in very high concentrations (100 fold above the effective dose of ADP which induced aggregation). Typical results are illustrated in Fig. 1 featuring the A•Ara system specifically.

When PRP was incubated for 30 seconds with any of the three compounds and then stimulated by a fixed dose of ADP, complete aggregation without significant time lag or diminution of magnitude occurred. There was no notable distinction among the three compounds and again, there was no dose dependent effect for any of these compounds over a 100-fold concentration range. Results for A•Ara are shown as a representative example in Fig. 2 along with the potent dose dependent inhibition produced within 30 seconds by adenosine for comparison.

With some adenosine analogs, potency of inhibition will change upon prolonged incubation with PRP (1). When PRP was preincubated with either E-Ad or MeAd for five minutes, no change in inhibitor

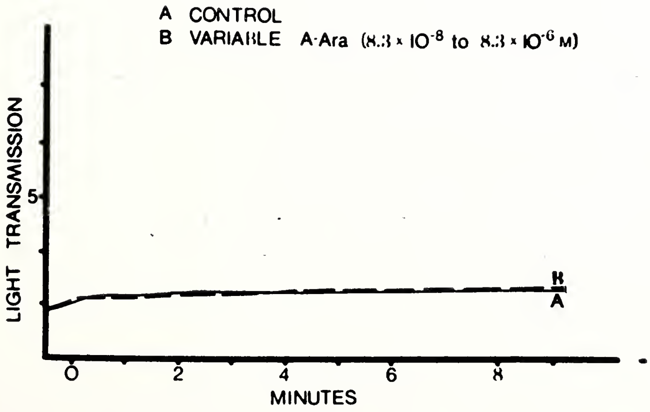


FIGURE 1. *Time dependent changes in light transmission through PRP suspensions after A•Ara is added. Curve A: control obtained by adding 0.05 ml. of 0.155M NaCl to PRP. Curve B: family of superimposed curves obtained by adding 0.05 ml. of A•Ara solutions; stock concentrations of A•Ara ranged from 1 x 10^{-5} M to 1 x 10^{-3} M.*

potency was observed when the platelets were stimulated by ADP. In contrast, a dose dependent improvement of inhibitor properties can be seen in Fig. 3 when PRP is preincubated with A•Ara for five minutes before ADP is added.

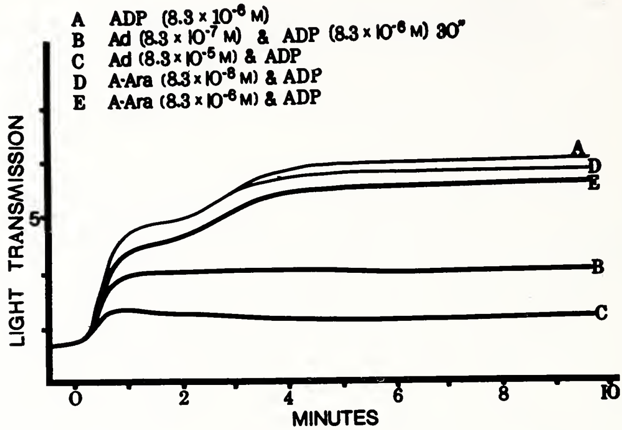


FIGURE 2. *Time dependent changes in light transmission through PRP suspensions preincubated with 0.05 ml. of variable concentrations of an inhibitor for 30 seconds. Zero minutes mark indicates the point at which the fixed (aggregation inducing) dose of ADP is added. Curve A: 0.05 ml. 0.155 M NaCl + 0.05 ml. 1 x 10^{-3} M ADP. Curve B: Low dose of adenosine challenged by aggregation inducing dose of ADP. Curve C: High dose of adenosine challenged by ADP. Curve D: Low dose of A•Ara + ADP. Curve E: High dose of A•Ara + ADP.*

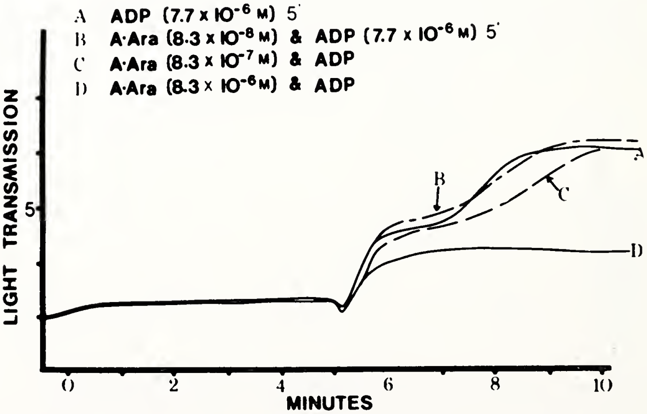


FIGURE 3. *Time dependent changes in light transmission through PRP suspensions preincubated with 0.05 ml. of 0.155 M NaCl, followed by 0.05 ml. of NaCl or A•Ara at 30 seconds (zero minute mark). A fixed ADP dose (0.05 ml.) is ultimately added at five minute mark. Curve A: Control; NaCl + NaCl (30") + ADP (5'). Curve B: NaCl + Low dose A•Ara (30") + ADP (5'). Curve C: NaCl + Mid-range dose A•Ara + ADP. Curve D: NaCl + High dose A•Ara + ADP.*

Discussion

It is unusual to find an adenosine analog with platelet aggregation stimulating activity; even the nucleoside phosphates, adenosine 5′ monophosphate and adenosine 5′ triphosphate, are inactive in this respect. Mester and Mester (7) postulate that the 5′ aldehyde product formed by chemical oxidation of adenosine is capable of inducing a mild and reversible aggregation since it possesses a partial negative charge at this essential molecular site. It is a necessary control in the screening of new compounds for platelet functionality to check for any aggregating properties, and the three reported compounds are devoid of this effect as shown in Fig. 1 with A•Ara as an example.

Other pentose variants of adenosine have been shown to be weak inhibitors of ADP induced platelet aggregation. The naturally occurring nucleoside, 2′ deoxyadenosine, is a very weak inhibitor as is 3′ deoxyadenosine (1). The 2′3′ dialdehyde product obtained from the periodate cleavage of adenosine has been shown to be devoid of inhibitor effect when incubated up to three minutes with PRP before ADP is added (7). It remains to be determined if loss of inhibitor effect in the dialdehyde compound is caused by loss of hydroxyls in a critical molecular region necessary for interaction with the platelet receptor or if loss of the rigid pentose ring conformation is the important structural determinant. In any case, the present pentose variants (A•Ara, MeAd) are shown to be poor inhibitors of ADP induced platelet aggregation when preincubated for 30 seconds with PRP.

Adenosine analogs which bear some similarity to E-Ad are reported by Kikugawa *et al.* (6) to be almost as inhibitory as is adenosine. Included in this series are compounds with bulky rings attached to the adenosine amino group (N^6-cyclohexyladenosine, N^6-phenyladenosine) (6). The present N^6 compound, E-Ad, is not completely analogous since the amino group is now part of an additional fused imidazole ring system rather than representing only the attachment of a bulky substituent at N^6 which is subject to relatively unhindered rotation. To account for the observation that E-Ad is not inhibitory while the compounds of Kikugawa *et al.* (6) are, it may be necessary to consider differences in pK of the amino group or differences in electronic charge at the various purine ring atoms in addition to substituent bulkiness.

Finally, it can be noted in Fig. 3 that only A•Ara improves as an inhibitor of the ADP induced platelet aggregation in experiments when the test compound is preincubated with PRP for five minutes before ADP is added. This is supported also by published A•Ara results of Agarwal and Parks (1) which report 20% inhibition of maximum aggregation for preincubation intervals of ten to sixty minutes. The time dependent change of inhibitor magnitude of an adenosine analog may be explained by slow conformational changes at the platelet membrane or by penetration of a compound and its entry into the metabolic or stored nucleoside phosphate pools within the platelet.

The present experiments suggest that the conformation of both the purine ring and the pentose moiety of adenosine are important determinants of inhibitor properties. Further investigation of structure-function relationships with nucleoside analogs may be of some value in the future design of antithrombotic drugs.

Acknowledgements

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ECOLOGY

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Indiana State University, Terre Haute, IN 47809

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Ball State University, Muncie, IN 47306

ABSTRACTS

Occurrence of the Protozoan parasite, *Henneguya exilis* Kudo, on channel catfish in Indiana. Raymond A. Schlueter, Division of Science and Mathematics, University of Tampa, Tampa, Florida 33606.——The Genus *Henneguya* belongs to a large and well-known group (Order Myxosporidia) of Protozoa which are typically parasitic on fish. *Henneguya exilis* is characterized by the spore being ovoidal, two polar capsules at anterior end, each shell-valve prolonged posteriorly into a long process, sporoplasm with an iodinophilous vacuole. *H. exilis* is found in gills and integument of *Ictalurus punctatus*, the channel catfish, forming conspicuous cysts up to 3 mm in diameter.

H. exilis has been reported in Illinois and in Iowa.

From June 1973 to August 1974, channel catfish were collected on a monthly basis from the White River near Petersburg, Pike Co., Indiana. Twelve out of 123 catfish had cysts containing the spores of *H. exilis.* These whitish pustules were found in the integument along the sides and caudal peduncle areas of the body. Only one fish (15 cm in Standard Length) was moderately infected. Most catfish had just a few cysts. The infection was only observed during the summer months (June through September).

It is not surprising to find *H. exilis* in the White River because Kudo (1934) states that *H. exilis* probably infects channel catfish living in major rivers of the Mississippi River drainage.

Black Locust as a winter food for Bobwhite Quail. Robert Priddy, Huntington College, Huntington, Indiana.——Black locust seeds ranked fourth in volumetric content and fifth by frequency of occurrence in crop content analysis of 398 bobwhite quail collected on the Salamonie Reservoir, northeastern Indiana, during the months of November through March, 1971-1975. Black locust was a major bobwhite food during January through March, and the availability of black locust seeds in periods of snow cover made this food source an important item in bobwhite winter diets.

Black locust seeds were fed to 20 pen-reared bobwhites during an eight-week period, March-May, 1976. A commercial flight conditioner was fed to 14 control birds during the same period. Males fed black locust seeds had the same change in weight as males fed commercial flight conditioner. Females fed black locust seeds and those fed commercial flight conditioner gained more weight than the males of both groups, however, females fed commercial flight conditioner gained significantly more than females fed black locust seeds. Birds that were fed black locust seeds consumed 37 percent more water than control birds and they defecated loose feces.

Changes Over a Half-Century in the Davis-Purdue Natural Forest. J. K. EICHENBERGER and G. R. PARKER, Department of Forestry and Natural Resources, Purdue University, West Lafayette, Indiana 47907. ——The Davis-Purdue Natural Forest, located in Randolph County, is one of the finest wet-site, oak-hickory stands in Indiana. The 20.6 hectare (51 acre) woods is among the largest old-growth remnants on the intensively farmed Tipton Till Plain. Since its acquisition in 1917 by Purdue University, the forest has been essentially undisturbed. The National Park Service has designated the forest a registered National Landmark.

An unpublished Purdue study was made of the tract in 1926. Each tree greater than 10 cm (4 inches) dbh was numbered, tagged, described in detail, and located on a large-scale map. Indiana forests offer few, if any, instances for which such complete prior data can be obtained. The present (1976) study re-examines the center 8.5 hectares (21 acres) with similar scrutiny. Changes in species composition, basal area, density, size-class relationships, and spatial pattern are being investigated.

A Comparison of Presettlement and Extant Forest Vegetation of Indiana. WILLIAM B. CRANKSHAW, Ball State University, Muncie, Indiana 47306.——A three-dimensional ordination of forests located on forty major southern Indiana soil types was constructed using absolute basal area. Derived from the original land survey data a second ordination using current basal area values was constructed for 18 stands, each of which occurred basically on one soil type. The comparison was made between the two ordinations for indications of temporal trends.

Preliminary Report on the Flora, Fauna and Habitats of the Swamp Rose Nature Preserve, St. Joseph County, Indiana. VICTOR L. RIEMENSCHNEIDER, Department of Biological Sciences, Indiana University at South Bend, South Bend, Indiana 46615.——The Swamp Rose Nature Preserve, about 40 ha in size, is located in the northeast corner of the new Potato Creek State Recreation Area. During 1975-76, 256 species and varieties of vascular plants have been identified in the three major habitat types, forest, upland old field and wetland, within the preserve. In addition, 62 species of birds have been observed within the preserve along with a few other species of amphibians, reptiles and mammals. The purpose of this study is to provide park personnel with base line data to determine management and use of the preserve. Complete species lists are on file with the Division of Nature Preserves and property manager of Potato Creek State Recreation Area. Plant specimens are presently located in the Department of Biological Sciences, Indiana University at South Bend.

Preliminary Observations on Reproductive Ecology of *Ambystoma tigrinum* (Amphibia: Urodela) in Northern Indiana. DAVID M. SEVER and

CLARENCE F. DINEEN, Department of Biology, Saint Mary's College, Notre Dame, Indiana 46556.——A long-term study began in 1976 on reproductive ecology of *Ambystoma tigrinum* breeding in a temporary pond in northern Indiana. *A. tigrinum* is the only salamander in the pond which at maximum size is .25 ha and 60 cm deep. Between 28 February-22 March, 172 adult specimens (125♂♂, 47 ♀♀) were captured by seining. Also, 14 specimens (7 ♂♂, 7 ♀♀) were caught from 29 February-14 March in 12 pit traps with drift fences set so that about 17% of the pond circumference was sampled. Schnabel and Schumacher population estimates based on mark-recapture of seined individuals predict 769-917 adults. Traps were turned 23 March so emigrating salamanders could be sampled, and 12 specimens were caught 29 March. Seining the pond 2 April produced no results. First egg masses were found 2 March and first hatching larvae 2 April. Larvae were unselective predators of any animals small enough to swallow. *Bufo* tadpoles were most frequent food items in May. Between 6 July-29 July, 158 newly metamorphosed *A. tigrinum* were caught in traps, 58% in the NEN-ESE directions. The pond dried completely 20 July, and many larvae were found desiccated, but heavy rains on 21 July refilled the pond and resulted in 35 trapped specimens after which no more larvae were found in the pond.

Viability and Growth Effects of Soil Applied Heavy Metals on Several Herbs Native to Northwestern Indiana. LARRY J. MILES and GEORGE R. PARKER, Department of Forestry, Purdue University, West Lafayette, Indiana 47907.——Preliminary results of greenhouse experiments indicate that soil applied heavy metal concentrations comparable to those encountered in the urban-industrial region of northwestern Indiana can affect the viability and growth of several native herbs. Viability appears to be more severely affected than growth. Plants grown on heavy metal impacted soil collected from an intensive study site in East Chicago do not show these effects. On the impacted soil, growth, at least for some species, was stunted, whereas viability was unaffected. These results indicate that some soil factor is limiting plant growth on the impacted site soil. This factor does not appear to be cadmium and may not be any of the heavy metals.

The Effects of Heavy Metal Contamination on Litter Decomposition in Northwestern Indiana. JOHN C. INMAN and GEORGE R. PARKER, Department of Forestry, Purdue University, West Lafayette, Indiana 47907.——The decomposition rate of three plant species, black oak (*Quercus velutina* Lam.), starry false Solomon's-seal (*Smilicina stellata* L.) and quaking aspen (*Populus tremuloides* Michx.) was monitored using nylon litter bags at a heavy metal polluted site and an unpolluted site. All three species of plant litter lost weight more slowly at the polluted site than at the unpolluted site.

Initial concentrations of all four heavy metals were greater at the polluted site than at the unpolluted site for all species of litter. As decomposition progressed, metal concentrations increased more rapidly in litter from the polluted site than the unpolluted site except for ZN and Cd in quaking aspen litter.

Microcosm laboratory studies were made on microfungal populations of contaminated and uncontaminated site litter using a leaf washing technique and the dilution plate method. There was no consistent difference in fungal populations on litter of Solomon's-seal and black oak from the two sites. The addition of $CdCl_2$ to uncontaminated litter had little effect on microfungal populations except for one species (*Aureobasidium* sp.). Counts also indicated a succession of fungi on the leaves, with Willow Slough treated and control litters being similar in succession but different from that of EC litter.

Impact of Phosphorus Removal on the St. Joseph River. LAWRENCE L. GARBER, Department of Chemistry, Indiana University at South Bend, South Bend, Indiana 46615, and MICHAEL J. JETER, Analytical Laboratory, Bureau of Sewers and Waste Water, South Bend, Indiana 46616. ——The installation of tertiary phosphorus treatment, which utilizes iron(III) chloride as a precipitant, at the South Bend Waste Treatment Plant has reduced the discharge of phosphorus into the St. Joseph River from approximately 2.1 g/sec to 0.7 g/sec. The total phosphorus removal at the plant is approximately 85 percent. Before phosphorus removal the effluent from the South Bend Waste Treatment Plant increased ortho-phosphate phosphorus concentration by about 88 percent. After phosphorus removal orthophosphate phosphorus concentrations increased by about 11 percent. The effluent had minimal impact on polyphosphate phosphorus and organic phosphorus concentrations for both before and after phosphorus removal.

Before phosphorus removal the range/mean for upstream orthophosphate phosphorus and polyphosphate phosphorus levels were 17-135 ppb/49 ppb and 8-53 ppb/22 ppb, respectively. The corresponding downstream parameters are for ortho-phosphate phosphorus 37-139 ppb/92 ppb, for polyphosphate phosphorus 9-65 ppb/25 ppb. After phosphorus removal the range/mean for upstream ortho-phosphate phosphorus, polyphosphate phosphorus and organic phosphorus were 44-162 ppb/68 ppb, 10-60 ppb/29 ppb, 21-118 ppb/50 ppb, respectively. The corresponding downstream values are for ortho-phosphate phosphorus 50-169 ppb/76 ppb, for polyphosphate phosphorus 10-84 ppb/28 ppb, for organic phosphorus 25-102 ppb/53 ppb.

Further Observations on the Seasonal Distribution of Brown Hydras. DONALD E. MILLER, Department of Biology, Ball State University, Muncie, Indiana 47306.——Observations, similar to those made from late June, 1972, to late March, 1974, and reported to the Ecology Section in 1974, were made from April 1, 1974 to March 31, 1976. All observations were made in Hamlin Lake, Mason County, Michigan.

Hydras were observed on natural and artificial supports. Most observations were made at shallow water situations. However, from April 25 to August 16, 1975, a float was anchored where the water was 10.5 m. in depth. Observations were made on artificial supports attached to this float about 0.5 m. below the water surface.

Observations at all stations, particularly on artificial supports, reaffirmed those made before and reported in 1974. Seasonal distribution was about the same. Accumulations of other organisms and detritus on supports did not seem to be important in excluding hydras from the supports or in determining the abundance of hydras on the supports.

The reason for the reduced population of hydras during July and August remains uncertain. Studies of hydras in other lakes, particularly during the period June through August, are recommended.

Those interested in more detail with regard to this problem are referred to the following: Trans. Amer. Micro. Soc., Vol. LV, No. 2, p. 123-193, April, 1936.

Aspects of the Symbiotic Behavior of *Periclimenes rathbunae* Schmitt and *Thor amboinensis* (De Man) with Their Host Tropical Sea Anemone, *Stoichactis helianthus* (Ellis), from Jamaica. DANIEL M. LEVINE and ORLAND J. BLANCHARD, JR., Department of Biology, Earlham College, Richmond, Indiana 47374.——*Periclimenes rathbunae* Schmitt and *Thor amboinensis* (De Man) are commonly found in association with the sea anemone, *Stoichactis helianthus* (Ellis) in depths of 1 to 6 feet. Neither shrimp species is ever found free-living. Specimens of *P. rathbunae* are usually found in pairs, with ovigerous females occupying the center of the oral disc near the mouth cavity, while males are restricted to the periphery. Specimens of *T. amboinensis* are usually found in groups of 3 or more in the immediate vicinity of an anemone, very often an anemone occupied by *P. rathbunae.* Behavioral studies indicate that *P. rathbunae* must acclimate to the stinging tentacles of its anemone host after a 24 hour period of isolation. In addition to this behavior, *P. rathbunae* exhibits many behaviors that parallel those of pomacentrid fishes in relation to their anemone hosts. These include territoriality, the storing of food on the host, agonistic behavior, grooming and cleaning the host and preference for specific hosts, as well as others. The anemone benefits from the presence of *P. rathbunae* by receiving scraps of food and by being constantly cleaned of dead cells and debris. The shrimp in return receives protection from predators and has an ever present food source in the form of material consumed duing the cleaning service it renders to the anemone. *P. rathbunae* and *S. helianthus* are therefore classified as mutual symbionts. *T. amboinensis* performs no services for the anemone and only seeks its protection when in danger. It is adapted for standing high above the stinging tentacles, and has an upright posture that also tends to minimize contact with the tentacles. *T. amboinensis* is classified as a commensal symbiont of *S. helianthus.*

Studies of the Cave Crayfish, *Orconectes Inermis Inermis* Cope (Decapoda, Cambaridae). Part I: Home Range. H. H. HOBBS III, Department of Biology, Wittenburg University, Springfield, Ohio 45501.——Two-hundred and eleven individuals of the obligate cave crayfish *Orconectes inermis inermis* (Cope) were externally and internally tagged in Pless Cave, Lawrence County, Indiana. During the two-year study period, 96 tagged individuals were recaptured at least once, a 46% recapture rate. The population size was estimated to be 1586 ± 79 over the 540 m study area. The size of the population remained relatively stable during the time of study.

Use of total range of movements indicates that the home range of male *O. i. inermis* is as large as 20 m and up to 23 m for females, although the maximum distances moved for both sexes greatly exceeds these values. Ranges of individuals overlap, suggesting direct competition among crayfish for food, space, mates, etc. Smaller individuals (male and female) are displaced greater distances downstream and larger crayfish show a significant upstream movement, however by pooling all the movement data, both sexes exhibit a net downstream movement. This downstream movement of individuals is greatly influenced by numerous and extensive spates which occur during the winter and spring months.

Volume Changes in an Old-growth Beech-Maple Forest over a 10-year Period

MARION T. JACKSON and D. BRIAN ABRELL
Department of Life Sciences
Indiana State University, Terre Haute 47809

Abstract

A tree-by-tree comparison of volume changes in an old-growth beech-maple forest over a decade revealed a 2.9% volume increase to 3,730 ft^3 per acre, and a 3.2% density reduction. American beech declined in volume, with yellow poplar, sugar maple and ash experiencing volume increases.

Introduction

Precise determinations of standing timber volume on a tree-by-tree basis over extended time periods are usually not made because of the difficulties in relocating specific individual trees, plus the excessive amount of labor required for such study.

This paper reports on a tree-by-tree comparison of a 10.87-acre (4.40-ha) portion of Hoot Woods, a 64-acre (25.9 ha) old-growth beech-maple dominated forest in Owen County, Indiana. Our study is a decade interval resurvey of the tract mapped at a 1:33 scale in 1965 (Jackson and Allen, 1967). Stand attributes and ecological changes during the decade were summarized by Abrell and Jackson (1977).

Methods

All trees above 8 inches (20 cm) dbh were measured to the nearest 0.1 inch with diameter tapes. Clear lengths of tree boles were measured to the nearest 1 foot (0.3 m) with a Spiegel Relaskop from a 1-foot stump to the upper limit of merchantability. Upper bole limit was delimited by branching, deformity or minimum diameter (8.0 inches, including bark).

Volume was computed separately for each tree on a Monroe Programmable Calculator Model 1860 based on the following rough (including bark) cubic foot volume formula of Beers (1964):

$$V = 92 \left[\frac{D^2 \ (D + 190)}{10^5} \right] \bullet \frac{1}{10^2} \left[\frac{H(168\text{-}H)}{64} + \frac{32}{H} \right]$$

where V = volume in rough cubic feet;
D = dbh in inches (to 0.1 inch);
H = clear length in feet

This formula was used as a composite calculation for all 17 species contained in the stand. The near-virgin stand (Petty and Lindsey, 1961) is high-canopied (ca. 120 ft or 37 m) with all species having little taper. Total volume was computed for all trees above the 8-inch threshold, including those dying during the decade, with no allowance made for hollow or low quality stems.

Tree nomenclature follows Little (1953).

Results

Volume data for 579 living and 40 dead stems are summarized by species by 8-inch size classes in Table 1. Overall, the stand volume

TABLE 1. *Summary of volume changes in a 10.87-acre sample of Hoot Woods during the 1965-1975 dccade.*

				1965-1975 Per Acre Volume Change (Ft^3)			Per Tree Values		
Species[1]	Size[2] Class	N[3]	1975 Volume (Ft^3/Acre)	Growth	Mortality	Net	$\overline{X}$ Diam. Increase (Ins.)	$\overline{X}$ Clear Length (Ft.)	$\overline{X}$ Vol. Increase (Ft^3)
Fg	12	96(8)	165	18.4	21.6	— 3.2	0.78	26.5	2.3
	20	102(8)	654	53.8	42.2	11.6	1.02	44.2	6.2
	28	80(9)	979	68.6	114.0	—45.4	1.02	50.3	10.5
	36	8(1)	160	1.9	12.2	—10.3	1.17	48.4	3.0
Subtotal		286(26)	1958	142.7	190.0	—47.3	0.94	40.1	6.0
Lt	12	27(1)	89	21.8	2.5	19.3	1.78	40.4	9.1
	20	31(3)	253	49.6	21.4	28.2	2.50	58.6	21.7
	28	7	118	19.0	---	19.0	2.39	69.3	29.5
	36	5	148	7.1	---	7.1	.86	78.3	15.4
	44	3	117	4.6	---	4.6	.83	80.3	16.6
Subtotal		73(4)	725	102.1	23.9	78.2	2.03	55.2	16.1
As	12	109(3)	183	38.3	5.8	32.5	1.29	26.5	3.8
	20	50(4)	302	29.1	36.0	— 6.9	1.35	48.0	9.6
	28	11	138	9.9	---	9.9	.96	50.2	9.8
Subtotal		170(7)	623	77.3	41.8	35.5	1.28	34.4	5.2

Fx		12	13	31	3.7	---	3.7	1.28	35.0	5.7
		20	12	91	23.2	---	23.2	2.47	54.0	19.9
		28	6	74	6.0	---	6.0	1.03	47.0	10.0
		36	1	24	3.3	---	3.3	2.30	62.0	36.0
	Subtotal		32	220	36.2	---	36.2	1.71	45.2	12.3
Other Species		12	42	77	16.6	---	16.6	1.54	25.8	4.3
		20	11(2)	51	6.8	8.4	— 1.6	1.24	42.6	8.2
		28	4(1)	41	6.3	20.8	—14.5	2.07	65.0	23.0
		36	--	---	---	---	---	---	---	---
		44	1	35	3.0	---	3.0	1.70	54.0	32.3
	Subtotal		58(3)	204	32.7	29.2	3.5	1.52	32.2	6.5
Totals			619(40)	3730	391.0	284.9	106.1	1.26	39.8	7.3

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[1] Species symbols are: Fg = *Fagus grandifolia* Ehrh.; Lt = *Liriodendron tulipifera* L.; As = *Acer saccharum* Marsh.; Fx = *Fraxinus americana* L. and *F. pennsylvanica* Marsh. Others = *Quercus muehlenbergii* Engelm., *Q. rubra* L., *Q. alba* L., *Prunus serotina* Ehrh., *Sassafras albidum* (Nutt.) Nees, *Ulmus rubra* Muhl., *U. americana* L., *Carya cordiformis* Wang. K. Koch, *C. glabra* (Mill.) Sweet, *Juglans nigra* L., *Nyssa sylvatica* Ehrh., and *Celtis occidentalis* L.

[2] Size classes in inches: 12 = 8.0 – 15.9; 20 = 16.0 – 23.9; 28 = 24.0 – 31.9; 36 = 32.0 – 39.9; 44 = 40.0 – 47.9.

[3] N = number of stems in 10.87-acre sample; numbers in parentheses represent the number of stems 8.0 inches diam., which died during the decade. Dead stems are included in the total N values.

increased during the decade from 3,624 to 3,730 ft^3/acre (Table 1). The 391 ft^3/acre growth increment during the decade offset mortality of 285 ft^3/acre, for a net gain of 106 ft^3 or a 2.9% increase. Only 21 trees grew past the 8-inch lower diameter threshold during the decade, as opposed to 40 tree deaths, for a net decline of 19 stems (1.7 per acre).

American beech, the leading species, declined 2.4% due to 26 deaths exceeding the collective growth of 260 remaining trees by 47 ft^3/acre. The co-dominant in basal area, sugar maple (Abrell and Jackson, 1977) increased by 6% to 623 ft^3/acre, largely by new accessions and growth in the 12-inch size class, offsetting a 2.2% decrease in the 20-inch size class. The 69 living yellow poplars increased an average of 16 ft^3 per tree for a net per acre gain of 78 ft^3, or a 12.1% increase to 725 ft^3/acre. White and green ash sustained no mortality and rapid growth for a 19.7% gain. Twelve minor species (55 living individuals) increased 33 ft^3/acre from growth, but had a net gain of only 1.7% due to the loss of a 31.7-inch wild cherry with 82 feet clear length.

Overall, the stems averaged 40 feet clear with yellow poplar the tallest at a mean clear bole of 55 ft. Seven poplars in the 28-inch size class added an average of 29.5 ft^3 of wood per tree (Table 1). Fastest growth rates were 20-inch size class yellow poplars and ashes at 0.25-inch average diameter increments per year (Table 1). Collectively, the stand averaged only 1.26 inch diameter growth for the decade. Beech, as expected grew most slowly.

Discussion

As old-growth forests mature, the average tree size typically increases, with corresponding declines in stem density. Hoot Woods followed this pattern during the past decade. Overall density declined from 598 stems (55 per acre) to 579, for a 3.2% density reduction. The corresponding overall volume increase was 2.9%. Such density-volume shifts obviously do not continue indefinitely. A point is reached at which the "over-maturity" of the stand creates instability within canopy individuals, as vulnerability of veteran trees to disease, insects and windthrow increases. Light gaps created by such processes provide invasion sites for more valuable (economically) species, such as yellow poplar and wild cherry.

Also interesting are the volume shifts for the co-dominants, beech and sugar maple. Although a decline in beech volume would be favored by foresters because of its low economic value, beech is a species of key importance in a research natural area such as Hoot Woods. Beech is considered to be the climax species for much of Indiana (possibly even over sugar maple), and as such has great value as a species for ecological research on forest equilibrium. Changes in the relative importance of both co-dominant species will be watched with keen interest during the coming decades. Such study should help clarify the nature of long-term stabilization toward the end of forest succession.

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The Effect of Suspended Solids on Macroinvertebrate Drift in an Indiana Creek

DAVID S. WHITE, University of Oklahoma Biological Station,
Kingston, Oklahoma 73439 and JAMES R. GAMMON,
Zoology Department, DePauw University
Greencastle, Indiana 46135

Abstract

The addition of small amounts of suspended solids to a normally clear stream produced a marked change in the macroinvertebrate drift rate. As suspended solids were increased, the number of drifting organisms showed corresponding increases to more than double the normal rates.

Introduction

Sediment is a pervasive, ubiquitous pollutant reaching water courses in the United States in quantities estimated at three billion m^3 annually. Poor farming, logging, and mining practices were the major contributors in the past, but now these have been joined by road and bridge building, and the proportion of sediment from urban construction may overtake that from agriculture in the near future (Wolman and Schick, 1967).

Large amounts of silt and sediment can cause drastic reductions in the lotic invertebrate populations when introduced into normally clear waters. Tebo (1955) found benthos reduced up to 75% with silt loads of 261 to 390 mg/l. Herbert et al. (1961) recorded decreases greater than 90% in streams receiving 1,000 to 6,000 mg/l suspended solids. Bartsch (1960) noted almost no organisms present when turbidity from a glass manufacturing plant exceeded 5,000 mg/l. Gammon (1970) and White (1970), however, found that a 60% reduction in the macroinvertebrate fauna could be caused by as little as a sustained 50 to 80 mg/l increase in suspended solids. Suspended solids causing sediment buildup may eliminate benthic populations by covering them over or destroying favorable habitats (Cordone and Kelly, 1961), but even light amounts of sediment not causing buildup may have profound effects on the benthos and fishes (Gammon, 1970; Reis, 1969).

Studies in the past 20 years have proven the downstream drift of invertebrates to be a good indicator of environmental conditions and changes occurring in flowing waters. Pearson and Franklin (1968) analyzed eight factors affecting the rate of benthic drift. Among these was the effect of turbidity. In one sample, they noted a sudden increase in turbidity from 20 to 700 mg/l was coupled with an immediate rise in the drift rate of a baetid mayfly. In other invertebrate drift studies by Reisen and Prins (1972) and those summarized by Bishop and Hynes (1969) and Waters (1972), little more is known of the effect of suspended solids on drift. From this, a series of experiments was designed to measure the effect of varying concentrations of suspended solids upon the drift rate of macroinvertebrates.

Study Area

Deer Creek is a small stream in Putnam County, Indiana, draining approximately 233 km^2. Arising on the southern edge of the Tipton Till Plain, it flows southwesterly for most of its 40-km length. The middle third of the stream is situated on the Mitchell Plain which produces renowned building limestone, and the lower third cuts through the more deeply dissected Crawford Upland. The section used for this study lies within the Upland at T 1- N, R 5 W, Sections 23, 24, and 26 near the town of Manhattan, Indiana.

The waters of Deer Creek are enriched by runoff from agricultural lands and treated domestic wastes. Chemical characteristics are typical for most east-central Indiana streams. Normal suspended solids usually are less than 100 mg/l. Discharge ranges from 125 m^3/sec to 0 m^3/sec and averages 1.8 m^3/sec; but stable flows from July through November average less than 0.2 m^3/sec.

Along the study section of the stream is a limestone quarry producing rock used mainly in road construction. In its operation, the quarry draws water from Deer Creek to be used in washing and sorting the crushed rock. The rock/water slurry containing the finer particles of limestone is then pumped to a series of two settling basins after which the waste water re-enters Deer Creek. The effects of the quarry washings on the stream biota have been presented by Gammon (1970) and White (1970).

A riffle above the quarry outfall was chosen for this experiment to eliminate any bias from previous sediment inputs. The riffle was characteristic of the stream, consisting of a mixture of large and small rubble on a bed of sand with a limestone base. Two large stands of water willow (*Justicia americana*) flanked the head of the riffle which was 25 m long, 8 m wide, and averaged 18 cm in depth. Previous studies have shown that this riffle had greater density and diversity of benthic forms than other riffles located directly above the quarry outfall (White, 1970).

Methods

To minimize other factors affecting drift rates, all tests were conducted during the early afternoon on clear days when the discharge of Deer Creek was less than 1.5 m^3/sec and the natural suspended solids load was less than 30 mg/l.

Placed at the foot of the riffle was a nylon drift net 1.83 m long with mouth dimensions of 30.5 cm x 61 cm and a mesh size of 253 μ. Metal stakes were driven into the substrate and fixed such that the net and frame could be removed quickly at the end of each timed period. A modified garbage can, which proved to be an adequate sediment dispenser, was placed near the head of the riffle. A large, square hole was cut on one side of the can near the bottom with a smaller hole being cut on the opposite side so that both openings would be below the waterline of the stream. A vertical baffle placed perpendicular to the direction of flow was then soldered to the bottom. When mixed thoroughly with the incoming water, sediment measured into the upstream chamber maintained a fairly constant load of suspended solids. The suspended solids could be regulated by increasing or decreasing the rate at which sediment was placed in the dispenser. Between the can and the net, the area of the riffle subjected to suspended solids was approximately 6 m^2. Prior to the first experimental runs, tests were conducted to determine if the operation of the dispenser caused any mechanical dislodgment of the benthos. Four 15-min simulated test periods were run without introducing sediment and each resulted in no increases to the normally occurring drift rate.

Material to be used as suspended solids was taken directly from the limestone quarry's settling basins. Particle sizes, determined by bottom withdrawal tube (Subcommittee on Sedimentation 1943, 1953), were generally less than 30 μ in diameter, with the garbage can being efficient in trapping most larger particles.

Experiments consisted of collecting benthic drift at the downstream end of the riffle for 15-min as a control followed by a 15-min collection during which solids were added continually at a given rate. The first control run was used to establish the naturally occurring drift rate before the riffle was disturbed. The alternation of conditions was repeated through several cycles with an attempt to maintain the same concentration of suspended solids in any day's test runs. The cycle was stopped at the first sign of sediment beginning to accumulate in the riffle; thus, the riffle usually was subjected to test runs for less than an hour on any particular day. The examination of higher or lower concentrations usually was separated by a period of days or weeks to prevent any cumulative reactions to the suspended solids.

Water samples were taken half way between the dispenser and net during each control and test. Suspended solids were measured using the methods of Banse et al. (1963) and Wyckoff (1964). Aliquots of 100 ml were filtered through tared Gelman Type-A glass fiber filters and oven dried at 105°C for 24 hours. The dried filters were then desiccated for 24 hours and weighed on a Cenco No. 1581 balance to the nearest 0.1 mg.

At the end of each drift period, the net was changed, and all material including debris was preserved in 70% ethanol. In the laboratory, macroinvertebrates were separated, identified, and counted. Identifications were made using the keys of Edmondson (1959) and Usinger (1963). To determine if the test and control runs were statistically significant, *t*-tests for paired comparisons were calculated following the methods of Sokal and Rohlf (1969).

Benthic collections, taken with a Surber square-foot sampler (0.3 m x 0.3 m), were used to compare the actual macroinvertebrate composition with the drift. The bottom samples were not taken on the same days as the drift; therefore, they are presented for comparison only.

Results

Table 1 summarizes the results of the drift experiments. The average amount of added suspended solids ranged from 18.6 to 271.3

TABLE 1. *Summary of alternating controls and tests; mean suspended solids± the standard error; means number of drifting organisms per 15 min ± the standard error; and values for t-test comparisons between periods of control and test drift. Number of trials in parentheses*

Run	Suspended Solids (mg/l) Controls	Suspended Solids (mg/l) Tests	Mean Added Solids	Drifting Organisms Controls	Drifting Organisms Tests	t_s	P
A	9.7±1.7(4)	28.3± 2.2(3)	18.6	32.0±4.3	40.3± 4.4	0.77	0.500
B	11.0±0.8(4)	65.3± 9.7(3)	54.3	25.0±6.2	33.0±10.0	3.03	0.100
C	24.0±1.2(3)	108.3±13.0(3)	84.3	19.7±5.2	28.7± 8.4	0.83	0.500
D	20.3±1.3(2)	125.0± 4.0(2)	104.7	62.0±6.4	117.5±25.0	37.48	0.025
E	27.7±1.3(3)	162.0± 2.8(3)	135.5	62.0±2.0	135.5±41.0	4.33	0.050
F	19.0±1.0(4)	173.5±38.2(4)	154.5	30.0±9.0	60.5±26.7	2.86	0.050
G	20.2±8.6(6)	291.5±46.5(6)	271.3	51.0±2.5	96.3±33.2	3.08	0.050

mg/l with corresponding increases in drift from 25.9 to 118.5%. The drift rate increased roughly linearly with the increasing suspended solids up to 135.5 mg/l added. Beyond this point, greater concentrations of suspended solids did not increase the drift to higher rates.

In those tests where the mean added solids were less than 100 mg/l, the increase in drift, although higher than in control runs, was not statistically different when *t*-tests were applied (Table 1). The four runs with greatest amounts of added solids did produce a significantly greater drift rate at least at the $P=0.05$ level.

All runs were made without stops between the cycles, control-test-control-test-etc. In each control that followed a test, the drift rate returned to the level of the first control, even during the runs with the greatest inputs of solids. Correspondingly, the drift response was immediate to the addition of suspended solids; and, at least at lower levels of input, did not proportionately increase throughout most runs. During the two series in which the greatest quantities of solids were added, there was a rather slow initial increase in drift and then a steady increase during subsequent test periods.

In order of abundance (Table 2), Chironomidae, *Simulium, Cheumatopsyche, Baetis, Caenis,* and *Stenelmis* comprised more than 95% of the drifting organisms. When compared with square-foot bottom samples, Chironomidae and *Simulium* were relatively more numerous in the drift than in the riffle while the other groups were either the same or less abundant in the drift. As the drift rate increased through higher concentrations of suspended solids, the numbers of Chironomidae, *Cheumatopsyche*, *Baetis,* and *Caenis* increased proportionally. The genus *Simulium* (mainly *Simulium vittatum* Zetterstedt) showed a decrease in drift during test runs until more than 100 mg/1 of suspended solids were added, with higher concentrations more than doubling the drift rate over the control periods. The riffle beetle (*Stenelmis sexlineata* Sanderson) showed no reaction to the suspended solids either as adults or larvae.

TABLE 2. *Percentage composition of macroinvertebrates from ft² bottom samples and from control and test drift trials.*

	Ft² Samples		All Control Runs		All Test Runs	
	Range	Median	Range	Median	Range	Median
Chironomidae	10-89	43	44-91	77	55-92	74
Cheumatopsyche	0-47	20	0-9	5	3-13	7
Baetis	1-10	8	0-14	4	0-15	6
Stenelmis	1-8	4	0-3	1	0-8	1
Simulium	1-17	3	0-28	6	0-16	7
Caenis	1-10	1	0-8	1	0-9	2
Others	1-30	4	0-9	1	0-9	1

Discussion

In previous drift studies, such as that by Pearson and Franklin (1968), the effect of suspended solids could not be separated from the effect of flow. Data from our experiments show that an increase in daytime drift rates can be related to increases in suspended solids without corresponding increases in flow. Up to a certain point, greater amounts of suspended solids produce a proportionate rise in drift rates.

Waters (1965, 1972) suggests that drift may be divided into the categories of constant, behavioral, and catastrophic. Drift also may be classified as active or passive (Müller, 1963). From our data, we cannot be sure how suspended solids influences the drift rate; but, at first glance, it seems to be an active-behavioral response. Additionally, it is difficult to state if the changes in drift rates are a reaction solely to the suspended solids or to other factors, such as light penetration, etc., that may change with the amount of solids added.

Most invertebrate taxa reacted similarly in relation to the increased suspended solids. The most notable exception was *Stenelmis sexlineata*. Even though this elmid is subject to distinct periods of diurnal drift (observations of the authors), it seems quite tolerant of suspended solids. *S. sexlineata* previously has been found to be indifferent to both turbidity and siltation (Sinclair, 1964; White, 1970); therefore, it would have been surprising to observe any reaction to the suspended solids.

Although repopulation occurs quite quickly through the natural drift from upstream riffles (Waters, 1972), high levels of suspended solids that increase drift rates over long periods could greatly affect the benthic fauna of a stream. In turn, this may reduce drastically the food supply available for stream fishes (Waters, 1969; Gammon, 1970).

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Analysis of Fluoride in Vegetation in the Vicinity of Wabash Smelting, Wabash, Indiana

JAMES T. STREATOR, Department of Chemistry Manchester College
SUSAN W. BURKHOLDER, I. U. Medical Center Purdue University

Abstract

Wabash Smelting Corp., Wabash, Indiana, processes scrap and used aluminum for reuse. In a number of court actions Wabash Smelting has been accused of contaminating vegetation and gaseous fluorides emitted from their plant. Analyses run in 1969 showed high fluoride levels in both annuals and perennials near the plant. Our study was designed to test for current levels of fluoride in selected vegetation within a two mile radius of the plant. Analyses were carried out using ashing techniques and determination of fluoride was done using a fluoride ion electrode. Results of the analyses are given and conclusions are drawn.

Introduction

Wabash Smelting Corp., Wabash, Indiana, is a secondary aluminum processor for the reclamation of aluminum from scrap. During this process, fluxing agents are added to scavenge impurities from the aluminum and remove dissolved gases. Also added are agents for reduction of magnesium (demagging agents) in the molten aluminum. AlF_3 is a common fluxing and demagging agent. The chemical reactions leading to purification of the aluminum also lead to the formation of solids such as MgF_2 and of gaseous products such as HF. Precipitators and scrubbers are used to remove the solids and gases. However, the possibility for environmental damage from poorly operating safeguards exists.

Wabash Smelting has been involved in a number of court actions dealing with exhausts from the plant. Fluoride analysis of vegetation collected around the plant were reported in late 1969 by J.E. Newman, Assoc. Prof. of Agronomy at Purdue University in a memorandum to the State Board of Health. All the samples tested showed fluoride levels ranging from 20-104 ppm. Of particular interest were high levels in sweet clover and alfalfa since these would reflect recent fluoride intake.

Sampling Sites

To see if there was evidence of recent fluoride contamination, it was decided to sample plants within a two-mile radius of Wabash Smelting at half-mile intervals as shown on the map in Figure 1. Plants chosen were plantain (Plantago major), red clover, and annual grasses. Not all three were found at every site. Since much of the land around Wabash Smelting is crop land, sampling sites had to be somewhat scattered, especially to the southwest. To the north, a new highway was being constructed and samples were not taken near the new road as considerable dust was raised by the construction. It was thought that this might produce spurious results. Samples were taken from public access sites or permission was obtained from farm residents to take samples from their property. If samples were taken near roads, care was taken to find samples protected from the effects of passing traffic, although this would be an uncontrollable variable.

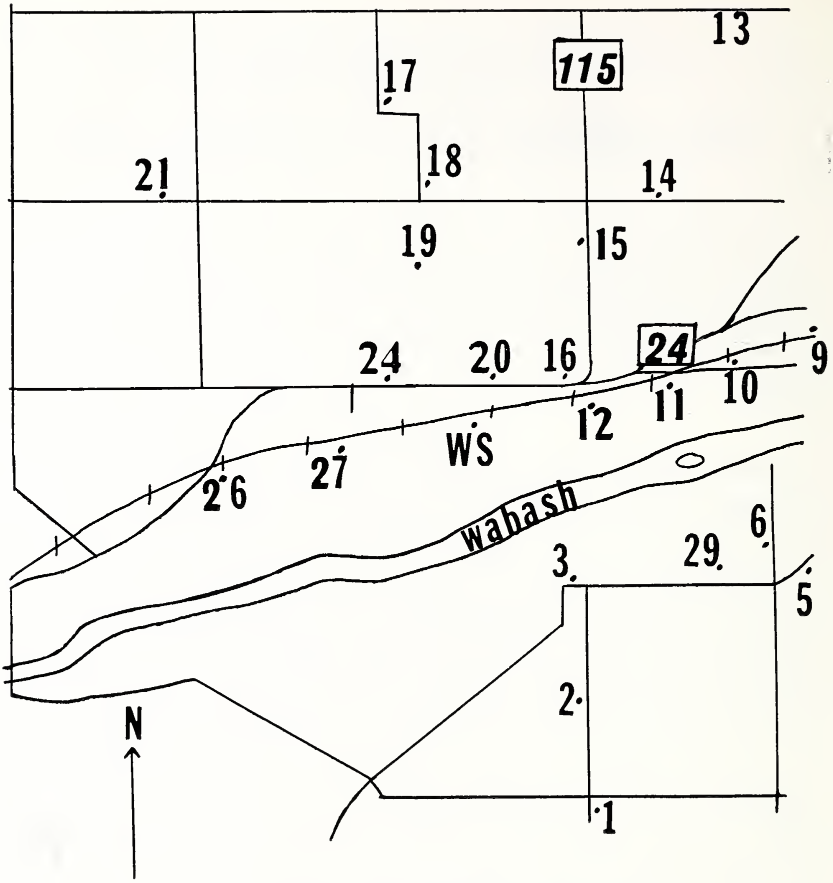

Figure 1. *Collection sites surrounding Wabash Smelting (WS).*

Only the leaves of the samples were tested. No attempt was made to wash off surface contamination so the results reflect both fluoride included in and on the plant tissue. It had rained lightly three days prior to sampling and the spring and summer weather prior to the time of sampling had not been unusually dry or wet. It was thought that wind patterns would be the most significant factor in determining fluoride concentrations although drainage patterns would probably also play a role.

Fluoride Analysis

The analysis used was a modification of procedures reported in references (1) and (2).

Vegetation was refrigerated as soon as possible. Samples were cut up and dried at 110°C for 24 hours. One gram samples were weighed into Pt crucibles and fused with base over a Fisher burner. The charred material was then placed in a muffle furnace at 520°C for 45 minutes. The crucibles were removed from the oven and the residue was dissolved in 8.5M acetic acid to produce a solution of pH 5.5-6.5. An appropriate amount of ionic strength adjustment buffer (Hach 2589-01) was added and the fluoride level was determined using an Orion fluoride electrode.

No standard samples for fluoride analyses in vegetation were available at either NBS or EPA. Our method of testing the procedures was to add a known amount of fluoride to vegetation of supposedly low fluoride content and perform the analysis. Over 90% of the added fluoride was found in the final analyses. Duplicate analyses run on samples from the same plant indicated that our analyses were at least accurate to ±25% for the lowest level fluoride and ±15% for the highest level.

Results

The results of the analyses are shown in Table I. As can be seen, only four of the readings were above 10 ppm of dry weight and three of the four were in samples of plantain. Clover samples all contained less than 5 ppm which is considerably less than the 90 and 24 ppm reported by Dr. Newman in 1969. Levels reported in Table I more nearly compare with the control sample of Dr. Newman although direct comparison is difficult. Dr. Newman dried samples in the air at 45% relative humidity and 76°F and it is not clear what parts of the plant were used in his samples. The present work used only the leaves dried at 110°C and stored in a dessicator over $CaCl_2$. However, given reason-

TABLE I. *Results of analyses of the indicated plants—All results are reported in ppm dry weight. ___ indicates that no samples of a particular plant were found at that site.*

Site Number	Grass	Plantain	Red Clover
1	2.5	---	---
2	4.6	1.6	---
3	8.0	2.1	2.5
5	2.5	2.5	---
6	1.6	1.3	1.8
9	1.6	---	---
10	2.5	1.2	---
11	2.1	2.0	---
12	---	3.0	---
13	2.0	20.5	0.6
14	10.2	1.7	3.1
15	3.5	---	4.2
16	1.8	---	---
17	2.8	14.5	2.5
18	---	1.6	---
19	2.1	2.2	---
20	5.0	3.8	3.2
24	3.5	15.0	---
26	2.8	1.2	---
27	2.2	---	3.9
29	2.5	---	4.6

able errors for both analyses, the 9 ppm reported by Dr. Newman might roughly compare with our results.

It would seem reasonable to conclude that no significant pattern of fluoride levels was found and, with only one exception (plantain site 13), levels of fluoride would have to be considered as typical (3, 4). No evidence of fluoride pollution at ground level caused by emissions from the Wabash Smelting was found.

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Food and External Parasites of the Norway Rat, *Rattus norvegicus*, in Indiana

John O. Whitaker, Jr.
Department of Life Sciences
Indiana State University

Abstract

Major ectoparasites of the Norway Rat in Indiana are the sucking louse, *Polyplax spinulosa*, the laelapid mites, *Androlaelaps fahrenholzi* and *A. casalis*, and the myobiid mite *Radfordia ensifera*. A number of other species were found in the fur, some of them parasitic, some not. Grain seeds (primarily wheat) and corn were the most important foods. These, plus other cultivated foods (Sorghum and Soybeans) totaled 62.1% of the volume of food in stomachs. It was estimated that *Rattus norvegicus*, in Indiana, eats a total of about 7000 tons of harvested crop foods on farms and at grain elevators per pear.

Introduction

The Norway Rat, *Rattus norvegicus*, is a very common animal, and often a major pest, but there is relatively little information on the food and external parasites of this species in Indiana. Wilson (14) examined 69 rats of this species for fleas, ticks and sucking lice. He reported 292 lice, *Polyplax spinulosa* (Burmeister) on this species from Lagrange, Marion and Tippecanoe Counties, Indiana, two ticks, *Dermacentor variabilis*, and four fleas, one *Ctenopthalmus pseudagyrtes*, one *Orchopeas howardii* and two *O. leucopus* from *R. norvegicus* from Indiana. However, 44 of the lice were from laboratory rats, rather than wild individuals. There are three earlier records of fleas from *R. norvegicus* in Indiana, the cat flea, *Ctenocephalides felis* (1), *Xenopsylla cheopis* (1, 13) and *Nosopsyllus fasciatus* from Marion County (13). *Xenopsylla cheopis* and *Nosopsyllus fasciatus* are both typically found on rats, but Wilson (16) found neither. There are apparently no records of mites from *R. norvegicus* from Indiana, although there are a number of records of mites from this species from elsewhere. Mite records for this species have been summarized by Whitaker and Wilson (15), and only a few of the more comprehensive reports will be specifically cited here.

The most pertinent paper geographically, would be that of Goode and Kocher (4). Those authors examined 392 live trapped Norway Rats from Louisville, Kentucky and recorded 3473 ectoparasites. Major forms included were 2512 lice, *Polyplax spinulosa* (6.41 per rat) on 281 rats (71.7% of them), 187 fleas, *Nosopsyllus fasciatus* (0.48) on 63 rats (16.1%), 167 mites, *Ornithonyssus bacoti* (0.43) on 41 rats (10.5%), 135 fleas, *Xenopsylla cheopis* (0.34) on 55 rats (14.0%), 69 mites, *Laelaps echidnina* (0.18) on 24 rats (6.1%). Sixty-three rats (16.1%) were entirely free of parasites.

A total of 8082 Norway Rats from Georgia was examined (10). Numbers of hosts parasitized, and numbers of individuals of major parasites are given below. ANOPLURA: *Polyplax spinulosa* (5440, 76,913).

SIPHONAPTERA: *Xenopsylla cheopis* (3056, 22,797); *Echidnophaga gallinacea* (1620, 18,324); *Leptopsylla segnis* (1680, 10,648); *Ctenocephalides felis* (238, 413); *Polygenis gwyni* (19, 23); *Orchopeas howardii* (4, 4); *Nosopsyllus fasciatus* (2, 3); and *Ctenophthalmus pseudagyrtes* (2, 2). ACARINA (Mites): *Ornithonyssus bacoti* (1365, 14,978); *Laelaps echidnina* (180, 1788); *Androlaelaps fahrenholzi* (90, 229); *A. casalis* (100, 175); *Hypoaspis lubrica* (29, 104); *Eulaelaps stabularis* (18, 71); *Macrocheles* sp. (5, 5); *Androlaelaps morlani* (1, 2); *Cheyletus eruditus* (46, 123); *C. malaccensis* (4, 4); *Radfordia ensifera* (1, 1). ACARINA (Chigger Mites): *Eutrombicula alreddugesi* (1, 1). ACARINA (Ticks): *Dermacentor variabilis* (52, 241); *Haemaphysalis leporis-palustris* (5, 5); *Amblyomma maculatum* (4, 6); *A. americanum* (2, 2).

Mellot and Connell (9) reported the mites *Echinolaelaps echidnina, Androlaelaps fahrenholzi, Ornithonyssus bacoti* and *Radfordia ensifera*, and the tick *Dermacentor variabilis* from *R. norvegicus* from New Jersey, but did not indicate abundance.

It is well known that Norway Rats are adaptable and will eat a large variety of items, and of course they are a major pest causing millions of dollars of damage in consumed or contaminated foods, especially stored grain. However, very few (if any) studies are available in which the food habits of this form have been studied via stomach analysis, either in Indiana or elsewhere. There are statements in the literature which refer to the food habits of the species, "Rats are omnivorous in their diet, eating any plant and animal foods that are available (8), and the rat is omnivorous. It is fond of garbage and food refuse, and is always attracted to a low open garbage pail. It feeds upon food stores wherever they may be found near the ground. It often visits a poultry house, and may destroy eggs in nests accessible to it. It will catch and kill baby chicks. In fact, it eats almost anything" (5).

Lantz (65) states The Norway Rat . . . "is the worst mammal pest in the United States, the losses from its depredations amounting to many millions of dollars yearly—to more, indeed, than the losses from all other injurious mammals combined. . . . It destroys grains when newly planted, while growing, and in the shock, stack, mow, crib, granary, mill, elevator, or ship's hold, and also in the bin and feed trough. It invades store and warehouse, and destroys fur, laces, silks, carpets, leather goods and groceries. It attacks fruits, vegetables and meats in the markets, and destroys by pollution ten times as much as it eats. It carries disease germs from house to house and bubonic plague from city to city. It causes disastrous conflagrations; floods houses by gnawing lead water pipes; ruins artificial ponds and embankments by burrowing; destroys the farmer's pigs, eggs and young poultry; eats the eggs and young of song and game birds; and damages foundations, floors, doors and furnishings of dwellings."

The purpose of this paper is to present information on the food and external parasites of the Norway Rat, *Rattus norvegicus*, in Indiana.

Results and Discussion

The major ectoparasites or other associates of the Norway Rat in Indiana (Table 1) are the sucking louse, *Polyplax spinulosa*, *Androlaelaps fahrenholzi* (Laelapidae), *Radfordia ensifera* (Myobiidae), *Androlaelaps casalis* (Laelapidae) and *Trichouropoda* sp. nr. *orbicularis*. No fleas, one chigger and only two ticks were taken, indicating these forms are not common parasites of *R. norvegicus* in Indiana. Indeed, other than for sucking lice, Norway Rats are surprisingly clean of ectoparasites. Of the 146 examined, only 86 or 58.9% were found to harbor parasites or other associates of any kind. Some of the forms taken on *R. norvegicus* in other parts of the country, were not taken or were taken in low numbers. Such forms among the mites were *Alliea laruei*, *Liponyssoides sanguineus*, *Eulaelaps stabularis*, *Laelaps echidnina* and *L. nuttalli*. The latter two species are very common parasites of *Rattus norvegicus* in many localities, yet none at all were found in Indiana. *Laelaps echidnina* was recorded in 25 separate papers

TABLE 1. *Ectoparasites (and other associates) from the fur of 146 Norway Rats,* Rattus norvegicus, *from Indiana. Asterisk denotes probable parasitic form.*

	Number of Parasites		Hosts Parasitized	
	Total	Mean	Number	Percent
LICE				
**Polyplax spinulosa*	2056	14.08	70	47.9
MITES				
**Androlaelaps fahrenholzi*	212	1.45	44	30.1
**Radfordia ensifera*	69	0.47	17	11.6
Trichouropoda sp. nr. *orbicularis*	40	0.27	16	11.0
Proctolaelaps hypudaei	23	0.16	6	4.1
Pygmephorus whitakeri	22	0.15	1	0.7
**Hypoaspis sp.*	21	0.15	6	4.1
Anoetidae	18	0.12	9	6.7
**Androlaelaps casalis*	18	0.12	15	10.3
Chortoglyphidae	11	0.08	8	5.6
Oribatid mites	10	0.07	4	2.7
Tyroglyphidae	13	0.09	5	3.4
**Ornithonyssus bacoti*	8	0.05	4	2.7
Macrocheles merdarius	6	0.04	3	2.1
Pygmephorus designatus	5	0.03	1	0.7
**Ornithonyssus sylviarum*	4	0.03	4	2.7
**Zibethacarus ondatrae*	4	0.03	1	0.7
Euryparasitus sp.	4	0.03	3	2.1
Macrocheles mammifer	3	0.02	3	2.1
Phytoseiidae	3	0.02	3	2.1
**Hypoaspis lubrica*	3	0.02	2	1.4
**Androlaelaps morlani*	1	0.01	1	0.7
**Hirstionyssus butantanensis*	1	0.01	1	0.7
**Androlaelaelaps sp.*	1	0.01	1	0.7
Glycyphagidae (adult)	1	0.01	1	0.7
Pygmephorus scalopi	1	0.01	1	0.7
**Cheyletus eruditus*	1	0.01	1	0.7
Macrocheles sp.	1	0.01	1	0.7
CHIGGER MITES				
**Eutrombicula alfreddugesi*	1	0.01	1	0.7
TICKS				
Dermacentor variabilis	2	0.01	1	0.7

from North American localities (15), although most of these records were from southern states, with a few from seacoast states of the northeast. However, *L. echidnina* is found on *R. norvegicus* in Ohio (7) and Quebec (3). Rats from Providence, R.I. were examined (11) and 21% were found to be infested with *L. echidnina.* Large numbers of this species were found on *Rattus norvegicus* from New Jersey (12). No difference was discerned in abundance on old versus young rats but average numbers per rat were much higher in warmer months than in colder months. Sixty-nine mites of this species were included among 3473 ectoparasites from 392 live trapped Norway Rats from Louisville, Kentucky (4). All of the 12 reports of *L. nuttalli* are for southern states (15).

Data from Indiana rats (mostly from central Indiana) can be compared to those from Louisville (4), just to the south and across the Ohio River from southern Indiana. The louse, *Polyplax spinulosa,* was the most common parasite taken during both studies. The percentage of hosts parasitized was lower in Indiana, but the overall average number per host was higher. However, there the similarity ended, as none of the other four more abundant parasites of rats from Louisville, 2 mites and 2 fleas, were abundant on Indiana rats, and three of them, including the two fleas and the mite *L. echidnina,* were not found at all. The other mite, *O. bacoti,* was found in low numbers (rate of 0.05 per rat, and on 2.7% of the rats). This is a common mite on the house mouse, *Mus musculus* in Indiana (2, 14); but is much less common on *Rattus* in Indiana or Louisville (0.43 per rat, and on 10.5% of the rats). It is not clear why rat fleas were not found on Indiana rats, but perhaps they are more common in the south. It would be interesting to examine rats from extreme southern Indiana. Possibly, rat fleas tend to move off the dead host faster than other fleas, but this seems unlikely; some fleas would have been taken if they were very common on central Indiana rats.

The two most common species of mites on rats from Indiana were *Androlaelaps fahrenholzi* and *Radfordia ensifera. A. fahrenholzia* is a common mite on many species of mammals. It seems peculiar that it was not taken in numbers on Louisville rats, since it is large and easily seen. *Radfordia ensifera,* a myobiid mite, is small and easily overlooked. One needs to use a dissecting microscope to examine the fur and skin of the rats while brushing the hair back with dissecting needles to find many mites of this species. I suspect that it was simply overlooked in the Louisville studies, especially since few other small mites were taken in numbers in that study either.

A fairly large number of forms was taken, at least 31, although not all have been identified to species. Also, not all of these were parasitic. Parasitic forms consisted of 1 species of louse, 12 species of mites and one species of tick. Many of the forms taken in low numbers must be considered as stragglers or accidentals, presumably having wandered onto the rats either before or after death. A few forms, *Trichouropoda* sp. and the species of *Macrocheles,* and *Pygmephorus* appear to be regular, though not abundant associates. Some of these may form phoretic relationships with the rats.

TABLE 2. *Foods eaten by 115 rats,* Rattus norvegicus, *from Indiana.*

Item	Percent Volume	Percent Frequency
Grain seeds (mostly wheat)	39.7	46.1
Corn	20.2	27.8
Flesh	6.3	10.4
Green Vegetation	5.3	12.2
Mast	5.0	6.1
Unidentified material	5.0	2.6
Miscellaneous vegetation	4.8	12.2
Clover flowers *(Trifolium sp.)*	3.9	8.7
Garbage	3.2	5.2
Grass seeds	2.1	3.5
Unidentified seeds	1.2	1.7
Sorghum seeds	1.1	1.7
Soybean seeds	1.1	1.7
Muscoidea	0.6	1.7
Dipterous larvae	0.2	3.5
Coleoptera	0.1	2.6
Formicidae (ant)	0.1	2.6
Earthworm	0.1	0.9
Unidentified insect	0.1	3.5
Coleopterous larvae	0.1	2.6
Adult Lepidoptera	0.1	0.9
	100.3	

Food Habits

Most of the rats examined during this study were taken in and around farms and grain storage areas, and this is reflected in the food habits data. The two top foods were grain seeds (mostly wheat) and corn, these two items totalling 59.9% of the volume of food in stomachs. These foods, plus the sorghum and soybean seeds in stomachs brings to 62.1% the total amount of cultivated crop foods in the sample. This was not grain left in the fields after harvesting; it was processed grain. If one considers that the amount of food per stomach might average 5 grams, that the stomach might be filled at least 3 times per day, and that approximately 60% of the food is of grain then it can be estimated that each rat might consume 9 grams of harvested grain per day x 365 days = 3285 grams per year. Assuming 25 rats per farm and 80 per grain elevator (probably low estimates), one can arrive at a rough estimate of the yearly amount of cultivated grains consumed per year by rats in Indiana. There are approximately 75,000 major farms in Indiana and approximately 770 granaries. Using the figures of 25 and 80 times these numbers the rat population of farms and grain elevators of the state was estimated at 1,936,600. Each rat destroys 3285 grams (7.2 lbs) per year. This calculates to 13,943,520 pounds (about 7000 tons) per year.

Other items were eaten, but most were of plant origin. Total animal material included 7.7% of the volume, mostly of flesh. Garbage comprised 3.2% of the total volume, but some of the other materials particularly flesh and unidentified material may have been of garbage.

In addition trace amounts of the following foods were found, each in one stomach: Unidentified insert larvae, Lepidopterous pupae, Hemiptera, *Chenopodium* seeds, Feathers, Cicadellidae, Phalangida, Cryptophagidae, Diptera.

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A Tree Census of Pre and Post-Tornado Forest Conditions of Happy Valley, Jefferson County, Kentucky

JOHN B. BAILEY and P. C. MACMILLAN
Department of Biology, Hanover College
Hanover, Indiana 47243

Abstract

A tree census was taken in a wooded valley which was struck by a tornado in April, 1974. Pre-tornado data indicated this was a near mature, second growth, sugar maple-buckeye community. Post-tornado analysis shows a loss of about one-third of the trees and a change to a sugar maple-white ash-swamp white oak community. This study affords baseline data to follow secondary succession within the forest.

Introduction

A tornado struck the Hanover College campus on April 3, 1974, and damaged a wooded valley, Happy Valley, northeast of campus. The partial destruction of the forest initiated secondary succession in the valley. The study site was the tornado blow-down area known as Happy Valley, which is located in the W½ Sec. 7 T3N R10E, Madison West Quadrangle, Jefferson County, Indiana (Fig. 1). The valley was a secondary growth sub-climax, mixed deciduous forest with good drainage from the uplands which surround the valley. The purpose of this study was to document the extent of forest destruction in the valley and to ascertain the immediate post-tornado condition of the woods so that future studies can evaluate the nature of forest recovery.

Pre-tornado data were obtained from class projects dating from the mid-1960's to the fall of 1973. The most useful was a project done in 1973 in which the class (Davis) transect paralleled the No. 2 transect in this study about 61 m to the south. Data from initial post-tornado study made in May 1974 was expanded into this report.

Methods

Point-quarter sampling (Cottam and Curtis, 1956) at 15.2 m intervals along three line transects, yielded phyto-sociological data. Nomenclature of tree species follows Gleason (1952).

Data analysis involved computations of relative values of density, frequency, and basal area which were averaged to yield percent importance (Cottam & Curtis, 1956). The tree data were divided into four diameter size classes as follows:

Class 1: 5.1 to 10.2 cm in diameter
Class 2: 10.2 to 20.4 cm in diameter
Class 3: 20.4 to 30.6 cm in diameter
Class 4: Greater than 30.6 cm in diameter.

A Hewlett-Packard 9820A was used for the statistical calculations. A program was written to calculate relative dominance and relative basal area per class size.

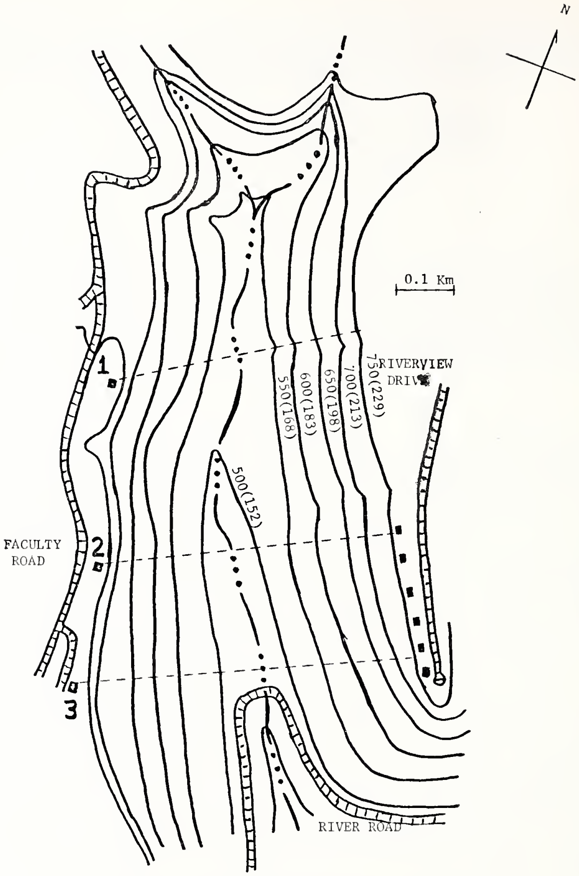
N
0.1 Km
RIVERVIEW DRIVE
750(229)
700(213)
650(198)
600(183)
550(168)
500(152)
1
2
3
FACULTY ROAD
RIVER ROAD

FIGURE 1. *Topographic map of Happy Valley study site. Numbers 1, 2 and 3 designate origins of each transect. Contour interval: 50 ft (15.2 m).*

Results

Transect No. 2 was used as representative post-tornado data (Table 1) as it closely parallels the pre-tornado (Davis) transect. Relative dominance and importance values could not be compared for lack of pre-tornado data. For an overall view of the blow-down area transect Nos. 1 and 2 are combined (Table 1). Transect No. 3 is not applicable here for an estimated one-half of it is outside the blow-down area.

A summary of the relative importance values from transect No. 2 is offered in Table 2. A comparison of percent importance by class size characterizes the species composition at different stages of growth, which in turn may represent a shift in species composition of the forest.

TABLE 1. *A comparison of pre and post tornado data of the forest stand. The following symbols are used in Tables 1 and 2: RD= relative density; RF= relative frequency; RIV= relative importance value; MD= mean distance; MA= mean area; T/H = trees per hectare.*

Davis transect			Transect No. 2		
Species	RD	RF	Species	RD	RF
Acer saccharum	45	31	*Acer saccharum*	64	42
Aesculus glabra	18	19	*Ulmus sp.*	8	12
Prunus virginiana	7	9	*Fraxinus americana*	5	9
Ostrya virginiana	5	7	*Aesculus glabra*	4	7
Quercus prinus	5	7	*Quercus bicolor*	4	5
Ulmus sp.	5	5			
Fraxinus americana	2	2			
Miscellaneous sp.	17	20	Miscellaneous sp.	15	25
Totals	100	100		100	100

Summary of pre and post-tornado tree census data.

Transect	MD(m)	MA(m^2)	T/H
Davis	4.42	19.56	511.7
No. 1	5.06	25.64	390.7
No. 2	4.66	21.78	459.8
Woods*	4.85	23.70	425.3

* Woods summarizes data from Nos. 1 and 2.

Discussion

In analyzing the summary data it is evident that pre-tornado conditions include greater numbers of trees per hectare along with a decreased mean area and mean distance per tree (Table 1). Post-tornado conditions indicate an increase in relative density and dominance in *Acer saccharum, Ulmus sp.* and *Fraxinus americana,* accompanied with a decrease of those values in *Aesculus glabra* (Table 1).

When the composition of the forest considers species percentage of importance by class size, the direction of succession becomes evident. In all four class sizes *A. saccharum* has a far greater relative importance value (Table 2). *U. sp.* has the second largest relative importance value in classes 1 and 3, third largest in class 2 and it is not represented in class 4.

The forest was previously an *Acer saccharum-Aesculus glabra* community. Analysis combining transect Nos. 1 and 2 using relative importance values indicates *A. saccharum* strongly established while *A. glabra* has been reduced greatly. Increasing dominance of *F. americana* and *Quercus bicolor* along with *A. saccharum* appear to characterize the beginning of secondary succession within the forest.

TABLE 2. *Species percent importance by size class using transect No. 2.*

Class 1		Class 2	
Species	RIV	Species	RIV
Acer saccharum	210.6	*Acer saccharum*	181.4
Ulmus sp.	26.8	*Quercus bicolor*	25.3
Cercis canadensis	18.3	*Ulmus sp.*	20.9
Fraxinus americana	16.2	*Fraxinus americana*	20.2
Aesculus glabra	16.2	*Celtis occidentalis*	11.6
Celtis occidentalis	8.5	*Carya cordiformis*	11.0
Tilia americana	8.5	*Juglans nigra*	10.4
		Quercus borealis	10.4
		Fagus grandifolia	8.4
Totals	305.1		299.6
Class 3		Class 4	
Species	RIV	Species	RIV
Acer saccharum	157.1	*Acer saccharum*	79.0
Ulmus sp.	45.4	*Juglans nigra*	55.0
Carya cordiformis	36.5	*Quercus bicolor*	51.8
Aesculus glabra	35.3	*Platanus occidentalis*	43.5
Celtis occidentalis	25.7	*Quercus prinus*	37.2
		Fraxinus americana	33.4
Totals	300.0		299.9

Acknowledgments

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Food Habits of the Spottail Shiner in Indiana Waters of Lake Michigan in 1973

ROBERT O. YAGER and THOMAS S. MCCOMISH
Department of Biology, Ball State University
Muncie, Indiana 47306

Abstract

Food habits of the spottail shiner, *Notropis hudsonius*, in Indiana waters of Lake Michigan were examined from June to October, 1973. Chironomid larvae, mainly *Chironomus* spp., and pupae were the major items consumed over the period on a volumetric basis (50%) followed by the epibenthic cladoceran, *Eurycercus lamellatus* (24%) and eggs of the alewife, *Alosa pseudoharengus*, (13%). Dominant food volumes consumed by month included: June, alewife eggs (47%); July, chironomid larvae and pupae (63%); August, *Eurycercus lamellatus* (48%); September, chironomid larvae (53%); and October, chironmid larvae (86%).

Introduction

The purpose of this study was to determine the food habits of the spottail shiner (*Notropis hudsonius* Clinton) in Indiana waters of Lake Michigan from June to October 1973. The food habit data collected were used to evaluate the trophic role of this species in the changing Lake Michigan environment.

No prior analysis of food habits of the spottail shiner has been undertaken in Indiana waters of Lake Michigan and only a few studies deal with this species in the lake. Willis (10) studied monthly and daily abundance of fish, including the spottail shiner, along several transects in Indiana waters in 1973. Wells and House (9) described aspects of the life history of the spottail shiner in southeastern Lake Michigan and Basch (1) presented information on food habits and age and growth in Little Bay de Noc.

Methods and Materials

Spottail shiners were collected along three Lake Michigan transects near Michigan City, Indiana, described in detail by Yager (11). One transect was established at Michigan City (M) with sample stations at depths of 1, 5, and 15 m. The other two transects were located west of Michigan City in the Dunes area (D) and at the mouth of Kintzele Ditch (K). Both D and K transects had sample stations at depths of 1 and 5 m.

Fish were collected twice monthly from June to October in 1973 by trawling and seining. Trawling at all transects and stations, except at the 1 m stations, was accomplished with a standard 5 m bottom trawl. Three tows were made at each station at both noon (11 am to 3 pm) and midnight (11 pm to 3 am) periods. A 12 m by 1.2 m nylon bag seine (3.2 mm square mesh) was used to seine at each 1 m station at the noon and midnight periods.

Fish were quickly removed from nets and preserved intact in about 10% formalin. Later, in the laboratory, a subsample of three fish per

5 mm length interval, when available, was taken for every day of collection and change in location or depth. Each fish was measured in total length and the stomach removed. The portion of the digestive tract used for stomach content analysis was composed of the first two turns of the tract. Stomach contents were then washed into a plexiglass counting cell and surveyed in strips under a binocular microscope using magnification from 40 to 100x. Organisms were identified to species when possible and counted to allow estimation of volumetric components. The volume of each food item was determined by measuring 30 representative intace organisms with the aid of an ocular micrometer and applying measurements to an appropriate figure as described by McComish (4). Volumes for organisms in an advanced stage of digestion were not determined because of the small amount of volume involved. When a volume estimation for a species was similar to data presented by Webb (8), his values were used.

Results and Discussion

General Food Habits

The primary food item groups consumed by spottail shiners ranging in length from 33-147 mm during 1973 (Table 1) were: insects, with a volume of 57%; zooplankton, 28%; and alewife (*Alosa pseudoharengus*) eggs 13%. Specific organisms in their order of importance in the diet were: *Chironomus* spp., which made up 25% of the volume

TABLE 1. *Yearly percent volume and percent frequency of occurrence of items in the stomach contents of 476 spottail shiners collected in Lake Michigan near Michigan City, Indiana in 1973.*

	Percent	
Organisms	Volume	Frequency
Zooplankton	28	(67)
Cladocera	27	(66)
Alona affinis	2	(36)
Bosmina longirostris	T	(23)
Chydorus spaericus	1	(24)
Eurycercus lamellatus	24	(55)
Copepoda	1	(15)
Cyclops bicuspidatus	1	(15)
Insecta	57	(77)
Diptera	50	(74)
Chironomidae larvae	27	(60)
Chironomus spp.	25	(56)
Others	2	(7)
Chironomidae pupae	23	(38)
Other adult insecta	7	(10)
Fish	13	(20)
Alosa pseudoharengus eggs	13	(20)
Miscellaneous organisms	2	(6)
Sand	P	(29)
Fish length range (mm)	33-147	
Mean length (mm)	101	

P = present but volume not calculated

and occurred in 56% of the stomachs; the cladoceran *Eurycercus lamellatus,* at a volume of 24% and occurrence of 55%; chironomid pupae, with a volume of 23% and an occurrence of 38%; and alewife eggs, at a volume of 13% and occurrence of 20%. Other items having limited volumetric importance (2% or less) but which were consumed frequently included the cladocerans: *Alona affinis* (36% occurrence), *Chydorus sphaericus* (24%), and *Bosmina longirostris* (23%); and a copepod: *Cyclops bicuspidatus* (15%).

The food items eaten by spottail shiners in this study have also been reported by other researchers. McCann (3) and Price (5) reported spottail shiners feeding on chironomid larvae, and McCann (3), Price (5), Smith and Kramer (7), and Basch (1) all report high amounts of cladocerans consumed. Spottail shiners feeding on fish eggs have also been reported previously (1, 6, and 7) and Edsall (2) has observed them feeding on eggs of spawning alewives.

The variety of food items consumed indicates spottail shiners fed on organisms at different levels in the water column. It appears, however, that major feeding activity was at or near the bottom since the epibenthic cladoceran *Eurycercus lamellatus,* chironomids, and alewife eggs were major food items. Further evidence for major near-bottom feeding activity comes from the relatively high frequency of occurrence for sand found in stomachs (29%).

Monthly Food Habits

Chironomids (larvae and pupae) were the major food items eaten by spottail shiners in all months of the study except June and August (Table 2; Fig. 1). *Chironomus* spp. accounted for at least 90% of the chironomid volume in all months and was the primary food consumed in September and October. Chironomid pupae were an important item in the diet from June through September and the major item consumed by spottails in July, which probably corresponds to a peak emergence period. Of the zooplankton consumed, only *Eurycercus lamellatus* was significant in volume and frequency of occurrence in more than one month. This cladoceran was the major food item consumed by spottail shiners during the month of August. Although *Alona affinis, Bosmina longirostris, Chydorus sphaericus* and *Cyclops bicuspidatus* were not volumetrically significant, they reached their peak in occurrence in the diet in August. Alewife eggs were consumed in large quantities as the major item in June and were a significant item in July. Sand was present in the stomachs during all months except September, indicating the spottails were feeding mainly near the bottom.

Summary

General food items of spottail shiners in Indiana waters of Lake Michigan for five combined months of 1973, in order of volumetric importance were: insects, including chironomid larvae (mainly *Chironomus* spp.) and pupae, the epibenthic cladoceran *Eurycercus lamellatus,* and alewife eggs. Fish were probably feeding mostly at or near the bottom as indicated by food consumed and occurrence of sand in stomachs.

TABLE 2. *Monthly percent volum eand personal frequncy of occurrence (parentheses) of items in stomach contents of spottail shiners collected at the 1 and 5m Lake Michigan stations near Michigan City, Indiana in 1973.*

Organisms	June	July	August	Sept.	Oct.
Zooplankton	10	22	52	23	3
	(55)	(65)	(86)	(57)	(36)
Cladocera	10	22	52	21	3
	(53)	(65)	(86)	(57)	(33)
Alona affinis	T	T	4	8	1
	(18)	(25)	(65)	(41)	(6)
Bosmina longirostris	T	1	T	T	T
	(8)	(21)	(42)	(10)	(6)
Chydorus sphaericus	T	T	T	2	
	(23)	(19)	(36)	(29)	
Eurycercus lamellatus	10	21	48	11	2
	(40)	(57)	(78)	(24)	(27)
Copepoda	T	T	T	2	T
	(14)	(13)	(21)	(17)	(3)
Cyclops bicuspidatus	T	T	T	2	T
	(10)	(10)	(20)	(16)	(3)
Insecta	42	67	43	76	92
	(53)	(85)	(78)	(88)	(97)
Diptera	30	63	38	71	86
	(47)	(81)	(78)	(88)	(88)
Chironomidae larvae	13	26	16	53	86
	(24)	(73)	(59)	(86)	(88)
Chironomus spp.	13	26	14	45	81
	(24)	(70)	(53)	(75)	(85)
Others	T	T	2	8	5
	(1)	(11)	(27)	(22)	(12)
Chironomidae pupae	17	37	22	18	
	(24)	(58)	(36)	(29)	
Other adult insecta	12	4	5	5	6
	(21)	(12)	(6)	(10)	(18)
Fish	47	11			
	(59)	(24)			
Alosa pseudoharengus eggs	47	11			
	(59)	(24)			
Miscellaneous organisms	1	T	5	1	5
	(4)	(2)	(8)	(6)	(18)
Sand	P	P	P		P
	(31)	(43)	(28)		(3)
Stomachs examined	102	144	148	49	33
Fish length range (mm)	37–145	64–147	37–141	33–140	42–136
Mean length (mm)	104	112	91	103	79

P = present but volume not calculated

On a monthly basis between June and October, chironomids were the major food consumed except in June and August. Alewife eggs were the major item consumed in June while *Eurycercus lamellatus* was the dominant August food.

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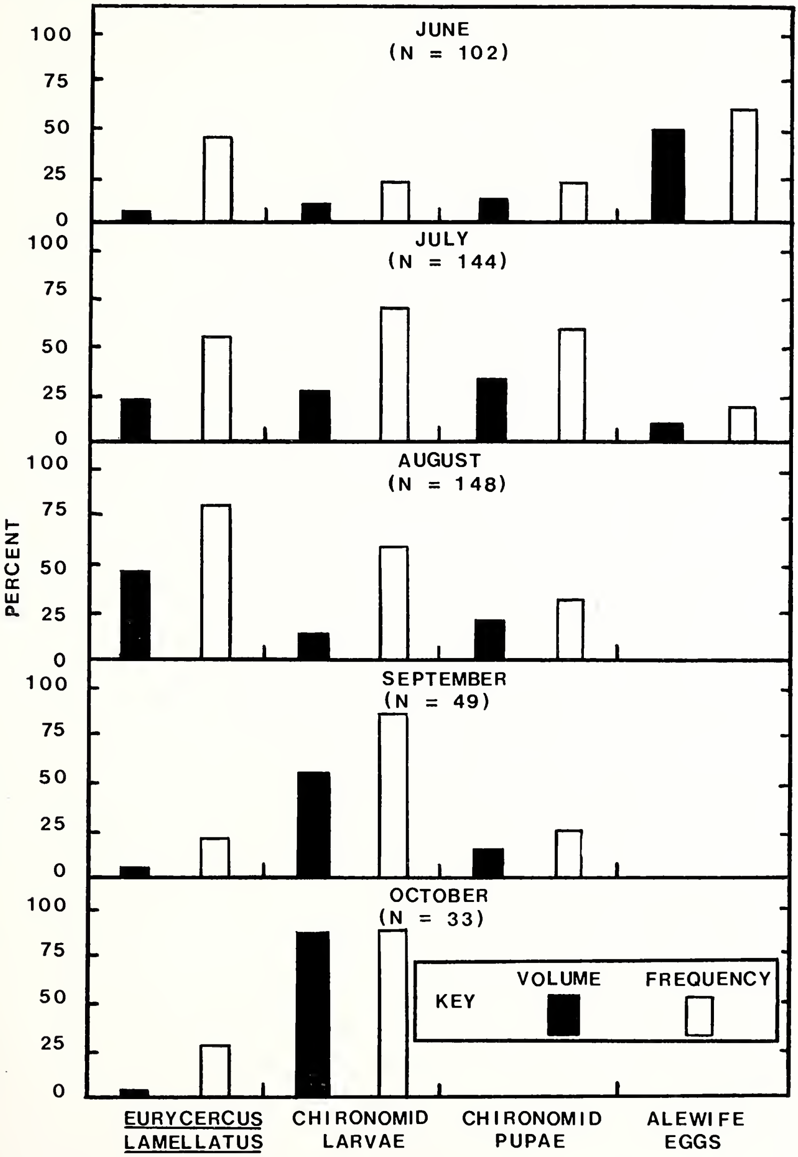

FIGURE 1. *Monthly percent volume and percent frequency of occurrence of the four major food items consumed by spottail shiners at the 1 and 5 m Lake Michigan stations near Michigan City, Indiana in 1973.*

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The Status of Indiana Streams and Fish from 1800 to 1900

J. R. GAMMON
Department of Zoology
DePauw University

Abstract

Early accounts of settlers remark about the clarity and beauty of Indiana streams and the abundance of fish. In the second quarter of the 1800's extensive changes occurred, changes resulting from clearing of land for agriculture and an ill-fated state program of canal building which was to facilitate transport of agricultural products to the Eastern states.

It is appropriate, if somewhat belated, in 1976 to look into the past and ask ourselves "What were the rivers and streams like way back before settlers from the south and east came to what is now Indiana?" Actually, this question has become a familiar one to those working in the area of aquatic ecology during the past decade, a period of unparalleled environmental soul-searching. We would like to, if we could, be transported back in time to observe first hand with our modern background the river primeval and examine the changes which accompanied the settling of Indiana.

Unfortunately, the first reliable scientific records about the nature of the fish populations as a whole date only from the 1870's when David Starr Jordan was just beginning in Indianapolis what was to become a distinguished career in higher education. While teaching at Shortridge High School and Butler University, Jordan and a colleague Herbert E. Copeland avidly collected fish from the White River and began studies of the life history of certain darters. They also collected at the Falls of the Ohio River near Jeffersonville, attempting to make sense out of the much earlier, hasty work of Rafinesque (1820). Jordan's first paper (1875) (subsequently republished in the Biennial Report of State Fish Commission, 1892) described the various species he had personally examined from the White River, the Wabash River, and the Ohio River. Taxonomic uncertainty abounded. The list was updated and clarified by Jordan (1877) and ultimately appeared with altered terminology in the excellent summary of Eigenmann and Beeson (1894).

This early scientific period was dominated by scientists who relentlessly sought to collect and catalogue new species of fish wherever they could be found, but few records remain as to abundance except in the most general terms. However, it was evident that the river at that time was not pristine, for Jordan noted in an address to the State Fish and Game Convention on December 19, 1899 ". . . That there never were such (smallmouth) bass streams as in Indiana, and that White River is the best bass stream they have ever known. I think probably nothing better could be done—if we could devise a way—than to bring the bass back, and where there are now a dozen scattering fish put two or three thousand." The seeds of an extensive stocking program were thus already sown prior to 1900. A few years earlier, the First Annual

Report of the Commission of Fisheries of Indiana (1883) carried Jordan's "Catalogue of the Fishes of Indiana" in an Appendix, but mostly discussed the coming availability of a great new species which would put fish back into Indiana lakes and streams—the carp. The Commissioners also discussed a recent fish-kill extending 20 miles downstream from Kokomo on Wildcat Creek, the result of pollution from a straw-board factory. If a new straw-board factory being constructed then at Anderson were to run its refuse into White River, they continued, "then it is "goodby fish" from Anderson to the Ohio River."

These few remarks are quite enough to convince one that extensive changes in the aquatic community had already occurred by the last quarter of the 1800's. In order to obtain a glimpse of what the rivers and fish were like before Jordan's time it is necessary to delve into diaries, travel notes, and historic papers. In 1800 there were perhaps 5000 whites in what was to become the state of Indiana, most in scattered small communities near rivers. Until 1815 few written accounts of the rivers and streams are available, although French fur-traders had lived in harmony with the Indians for at least a century previously. Indian opposition to settlers moving north of the Ohio River had been dealt with by that date and settlers entered in increasing numbers because of the rich agricultural lands.

Caleb Lownes in a letter to Oliver Wolcott (Sec. Treas. under Presidents Washington and Adams) wrote in 1815 (see McCord, 1970) . . . "The first rate lands lie on the Wabash all the way to the lakes on the most beautiful stream in my recollection—it is about 250 yards wide at this place (Vincennes) and preserves its width very nearly for 400 miles. . . . It is a beautiful and valuable stream—the water generally perfectly clear and transparent—exhibiting a clean gravelly bottom—It abounds with fish of various kinds—Bass-Pickerel, Pike-Perch-Catfish &c. The Catfish are of every size up to 122½ lb. one of this size was caught (at Fort Harrison 80 miles above this)—The perch (probably smallmouth bass) are from 12 to 20 in length-this appears to be dealing in the marvelous but it is nevertheless correct—a large White fish about 2½ feet long with very little bone was yesterday caught by a gentlemen on a party said to be excellent."

Most of these early accounts focused on the fertility of the land and the rivers were examined mostly from their ability to provide sites for mills and water for floating boats loaded with future produce. Thus, Enoch Honeywell writes in his diary (see McCord, 1970); "Apr (May) 1816. saw ft Harrison. there is about 12 families living in and near the fort and 10 to 12 more at 6 miles distance southeast 2 at 8 miles south, which are all of 25 miles. The river here is 50 to 60 rods wide, very deep, clayey banks, always navigable for keel-boats except over the grand rapid below Vincennes in low water. In freshes it inundates its banks very bad; on the west side the river here it floods about a mile, but the soil being light the water soon drains of or soaks in."

By far the finest early account of the area is that of David Thomas (1819). Had his interest in rivers and lakes been half that of his interest in vegetation and wild life we would have a very detailed, clear account of aquatic life, indeed. Nevertheless, some illuminating comments about the Wabash River as far north as Otter Creek were made.

"The water of the Wabash forms a good lather with soap, At Pittsburgh, for washing, the river water was good, but it becomes harder in its descent. At Cincinnati an increase of lime was evident; and near the mouth of the Wabash, the water of the Ohio was hard" . . .

"The Wabash has a gentle current, except at the Rapids, twenty-three miles below Vincennes" . . .

"The Wabash is four hundred yards wide at its mouth, three hundred at Vincennes, and two hundred at Fort Harrison. It is fordable in many places."

"Whenever a high piece of land appears on one side of the River, the opposite shore is low and sunken; and from Raccoon Creek, fifteen miles above Fort Harrison to the mouth of the river, I believe there is no exception to this remark.

There is one inconvenience attending this country, exclusive of the overflowing of the Wabash. All its tributary streams after a heavy shower of rain, rise above the banks; and overflow the low land adjoining, which on all, is of considerable extent. In time of high water, it is one of the most difficult countries to travel through, I ever saw. I have known it for more than four weeks at one time, that no person could get away from Union Prairie without swimming his horse, or going in a boat."

"The Wabash abounds with fish of many kinds; which, in the months of April, May and June, may be readily caught with the hook and line."

"The Gar or Bill fish is more than two feet in length. It is quite slim. The bill is about six inches long, tapering to a point. Its scales are very close, thick, and hard."

"The strength of this fish is great. In a small creek which flows into the Wabash, I discovered a considerable number, and caught several in my hands; but was absolutely unable to hold one."

There are three kinds of Cat-fish: the Mississippi cat, the mud cat, and the bull head. Some of the first have weighed one hundred and twenty pounds. The mud cat is covered with clouded spots and is a very homely fish. The head is very wide and flat. Some have weighed one hundred pounds.

"The real sturgeon is found in the Wabash, though the size is not large. These have been taken from twenty to sixty pounds weight.

"The shovel fish or flat nose is another species of sturgeon. It weighs about twenty pounds.

"The pond pike is taken in ponds from one to three feet long, but very slim. It is an excellent fish. (Northern pike)

"The river pike is large and highly esteemed, but scarce. (Muskellunge)

"The drum or white perch weighs from one to thirty pounds. It is shaped like the sunfish.

"The black perch or bass is excellent, and weighs from one to seven pounds. (Smallmouth bass)

"The streaked bass is scarce. (White bass)

"The Buffalo fish is of the sucker kind, and very common. Weight from two to thirty pounds.

"The rock Mullett is sometimes seen three feet long. It is slim and weighs from 10 to 15 pounds. (Smallmouth buffalofish?)

"The red horse is also of the sucker kind. It is large and bony, weighing from five to fifteen pounds.

"The Jack pike or pickerel is an excellent fish, and weighs from six to twenty pounds." (Walleye pike)

In another communication, I found the silver-sides noticed without any description. "It weighs from three to six pounds."

The eel is frequently taken in the Wabash, and weighs from one to three pounds. I was told that no fish was found in these waters of a good quality for pickling; and the facts, that mackerel are brought over the mountains from Philadelphia, and white fish from Detroit, tend to confirm that statement.

"The fresh water clam or muscle is so plenty, as to be gathered and burnt for lime. Twenty years ago, I am told, no other kind of lime was procured."

"Craw fish, which resembles the lobster, is very common in the low lands of this country. It is a size larger than the common crab. It works in the ground, and throws up heaps of earth about six inches high, and hollow within. These little mounds are very numerous, and the surface of the ground resembles a honey comb."

Thomas commented also upon the frequency of sick people, many of them newcomers, and gives some recommendations to the traveler and new settler, among which: "Let no temptation prevail on the emigrant to go fishing in warm weather. Of the smell of the shores I have spoken. To be wet is imprudent; and to be exposed to the chilling damps of the night, greatly increases the danger. But fresh fish are unwholesome, except for a slight change of diet. We know of no new settlement that has been healthy, where the inhabitants live chiefly on fresh fish. If, however, fish must be eaten, buy them; any price is cheaper than health; and if fishing must be done, do it in cloudy weather; but at night be comfortably sheltered."

The great clarity of water was remarked upon by more than one observer.

". . . This beautiful little river (the Whitewater) waters nearly one million of acres of fine land, and owes its name to the unusual transparency of its water. A fish or a pebble can be seen at the depth of twenty feet." (Brown, 1817 in McCord, 1970).

General John Tipton, one of the men charged with selecting a site for the new state capitol crossed Fall Creek where he "saw plenty of fine fish . . ." (Tipton, 1820), and described an oxbow lake near what is now the Marion County line as ". . . a beautiful clier pond or lake about 60 yards wide seeming nearly from n to s the water clier the Bottom gravley a plenty of fish" as well as Spring Lake near Martinsville . . . "Saw a beautiful lake, 1 mile long and 100 yds. wide, clier water, sandy bottom . . . I am told the river in a high stage runs into it."

"It was in the month of April (1825) when I first saw the Wabash River . . . Schools of fishes—salmon, bass, redhorse, and pike—swam close along the shore, catching at the blossoms of the red-bud and plum that floated on the surface of the water, which was so clear that myriads of the finny tribe could be seen darting hither and thither amidst the limpid element, turning up their silvery sides as they sped out into deeper water." (Cox, 1860).

Fish were plentiful and easy to obtain at this time.

"At John Stitt's mill below town (Crawfordsville), on Sugar river, there is a fish-trap, and in one night we caught nine hundred fish, the first Spring we were in the country (1825), most of them pike, salmon, bass, and perch. Some of the largest pike and salmon (Walleye) measured from two to four feet in length, and weighed from twelve to twenty-five pounds." (Cox, 1860).

Rafinesque (1820) stated "Fishes are very abundant in the Ohio, and are taken sometimes by the thousands with the seines. . . . The most usual manners of catching fish . . . are, with seines or harpoons at night and in shallow water, with boats carrying a light, or with the hooks and line, and even with baskets."

Species of fish which Rafinesque regarded as abundant or common in the Ohio River included: drum, the three species of black bass, bigmouth buffalo, shovelnose sturgeon, channel catfish, yellow bullhead, goldeye, mooneye, emerald shiner, golden shiner, log perch, greenside darter, and fantail darter. Hook and line fishing was too slow for the settler and, in addition to seining, spearing and gigging were popular in clear water streams containing an abundance of fish.

Dunn (1910) records the abundance of fish in the White River according to early residents of Indianapolis as follows:

"George W. Pitts commented "There was no end of fish in the streams in those days. I went up to McCormick's dam (just above the Country Club) four miles above town on the river one day and sat down at a chute that had broken out and where fish were running through. There were wagon loads of fish, and I threw out with my hands eighty-seven bass, ranging in size from one pound up to five."

"Amos Hanway says there were 'bass, salmon (walleye and/or sauger), redhorse, ordinary suckers, quillbacks, or as they were sometimes called spearbacks, perch, pike, catfish, etc. The biggest salmon I ever caught weighed sixteen pounds. I once caught a pike that measured four feet and two inches (Muskellunge); at another time a gar-fish that measured over three feet, and a blue catfish that weighed sixteen and a quarter pounds. The finest rock bass (large-mouth bass) I ever took was one which weighed eight and a quarter pounds, and that was near Waverly; while the biggest river bass (smallmouth bass) I ever lifted from the water weighed six and one-fourth pounds.' " He went on to say that once in Morgan County, above the Cox dam, when the fish were running, he and his brother Sam "at one haul seined twelve barrels of fish, and there were thirty fish that averaged, undressed, ten pounds each. They were mostly bass and salmon, but there were also large redhorse, white perch, quillbacks and ordinary suckers."

The importance of an abundance of excellent fish is stressed. Flint (1826, in Lindley, 1916):

"The streams, and especially those that communicate with lake Michigan, are abundant in fish of the best qualities. The number and excellence of the fish, and the ease, with which they are taken, are circumstances of real importance and advantage to the first settlers, and help to sustain them, until they are enabled to subsist by the vails of cultivation."

Great changes were to occur between 1830 and 1845, as Cox (1860) poignantly writes:

"I can well recollect when we used to wonder if the youngest of us would ever live to see the day when the whole of the Wea plain would be purchased and cultivated; and our neighbors on the Shawnee, Wild Cat, and Nine Mile prairies were as shortsighted as we were, for they talked of the everlasting range they would have for their cattle and horses on those prairies—of the wild game and fish that would be sufficient for them, and their sons, and their sons' sons. But those prairies, for more than fifteen years past, have been like so many cultivated gardens, and as for venison, wild turkies and fish, they are now mostly brought from the Kankakee and the lakes."

The changes, of course, came about as the direct and indirect result of a rapidly increasing population and establishment of extensive agriculture which led, in turn, to the exportation of surplus agricultural goods. In 1800 the population of Indiana was only 5,641 (Melish, 1822 in Lindley, 1916). In 1810 it was 24,520; in 1815, 68,784; and in 1820 it was 147,178 including whites, free blacks, and slaves, but not counting indians. These early residents found a ready market for their surplus agricultural products in New Orleans and floated them on flatboats down the Wabash and White Rivers to the Ohio and then on to New Orleans during the spring floods. However, by 1827 the New Orleans market became saturated and ways were sought to transport the goods to and from the eastern markets (Esarey, 1912). By this time, steamboats were regularly plying Wabash waters up to Terre Haute and, sometimes, Ouiatanon south of Lafayette.

An effort began to create navigable waters throughout the state, but the physical clearing of the land itself acted against this need.

"Unquestionably White River is not so easily navigable now as it was ninety years ago, though probably as much water passes out through its channel in the course of a year as there did then. The flow is not so steady because of the clearing of the land and improved drainage make the surface water pass off more rapidly. And this has increased the obstructions in the streams, for the soil, sand, and gravel wash much more easily from cleared land. Moreover, in the natural state, most of the timber that got into the river came from the undermining of banks on which it stood, and this usually did not float away but hung by the roots where it fell. But after the axmen got to work, every freshet brought down logs and rails which formed drifts at some places. Some logs stranded as the water went down, decayed, became waterlogged, and made bases for sand and gravel bars." (Dunn, 1910)

Erosional pollution as an important altering factor soon had a powerful ally when the state began an extensive, but unrealistic program of canal building from 1828 to the mid 1850's. Beginning at Fort Wayne in 1828, the Wabash and Erie Canal crept steadily westward toward the mouth of the Tippecanoe River, which was considered the head of navigation for the Wabash. By 1834 about one thousand Irishmen were at work when they weren't drinking or fighting. By this time the entire state clamored for canals. An appropriation was asked to open almost every stream in the state large enough to float a canoe (Esarey, 1912).

The upper portion of the Wabash and Erie Canal was in operation by July 4, 1835, but the tolls were inadequate to keep it in repair. The wooden aqueducts were already rotten. In 1836 construction was begun on the Whitewater canal and when completed in 1839 it included two large dams. Also in 1836, several sections of canal were constructed on the White River and a 19 mile section on Pigeon Creek near Evansville which, when completed, went completely dry.

Meanwhile, the Wabash and Erie Canal crept southward, reaching Lafayette in 1843 and Terre Haute in 1847. As originally planned, the canal was to connect with the Wabash River at Terre Haute. However, it was decided to extend it on to the Ohio River via the lower portion of the Central Canal which was to be constructed to Indianapolis. Thus, the canal proceeded southeast to the Eel River, on past Worthington and Bloomfield, and to Maysville just west of Washington. It continued on south through Petersburg, crossed the Patoka and finally linked up with the canal at Pigeon Creek.

Throughout the 1840's difficulties were encountered in supplying sufficient water to that part of the canal south of Lafayette and, as a result, so-called "feeders" were developed from tributaries all along the canal. The problem was particularly aggravating below Terre Haute and dams were constructed across Splunge Creek, Adams Creek near Monrovia, and Birch Creek at Saline City. The six square mile reservoir at the latter site was subject to frequent acts of sabotage because it was believed to be the cause of a malaria outbreak and finally was drained completely.

The aggregate damage to stream habitat during this period can only be inferred since few descriptive records exist, but it must have been significant, and, as it soon turned out, completely for naught.

Navigation was abandoned south of Terre Haute in 1860 and by 1870 little more than a succession of stagnant pools marked the site of the canal (Esarey, 1912), a casualty of gross fiscal mismanagement and competition from railroads.

Thus by the time Jordan arrived in Indiana in 1874, extensive alterations in the native fish populations had already occurred, alterations at first resulting from clearing land for fields and building dams for grist mills and a bit later the wholesale destruction of habitat in a gigantic state effort to provide better commercial links between the fledgling state of Indiana and the eastern seaboard. Jordan was in time, however, to witness the first side effects of industrial development in Indiana, a development which would superimpose an additional heavy burden on the waters of Indiana.

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Ecological Adaptation of Certain Forage Species on Shallow Muck Soils

B.O. Blair, C.L. Rhykerd, R.E. Mullen, W.O. Jones, and J.J. Vorst
Department of Agronomy, Purdue University
West Lafayette, Indiana 47907

Summary

Most of the million plus acres of muck soils in Indiana suitable for agriculture are used for corn, soybean or vegetable crop production. Continued production of these crops have, in many cases, introduced severe weed problems. Field operations necessary in culturing these crops in poorly drained fields often cannot be accomplished at the proper time and returns are marginal. Cold air drainage into these areas in early fall frequently results in killing forests which shorten the season as much as three weeks. In many cases it is necessary to harvest corn as silage and soybean yields are appreciably reduced.

These problems prompted an investigation at the Pinney Purdue Agricultural Center at Wanatah, Indiana, relative to utilizing these areas more profitable by seeding to forage grasses and legumes. The experimental area is shallow, due to a long history of wind erosion. The muck soil in this area varies from 45 to 100 cm in depth. A small plot study demonstrated that the water table at 70-85 cm prohibited the production of many commonly grown perennial forage species. *Bromus* and *Medicago* species, however, grow satisfactorily in surrounding areas.

This article reports on the successful conversion of a 50 ha muck area from warm-season annual crop production to a permanent pasture composed of Kentucky bluegrass (*Poa pratensis*) a cool-season perennial grass and birdsfoot trefoil (*Lotus corniculatus*), a warm-season legume with a shallow root system. In addition, it was found that a Kentucky bluegrass-birdsfoot trefoil mixture can be a highly productive alternative to corn or soybeans on shallow muck soils where adequate animal units are available for utilizing the early spring growth of Kentucky bluegrass and the later growth of birdsfoot trefoil.

Introduction

In Indiana, muck soils are estimated to occupy .5-.6 million ha most of which are in the northern third of the state. These soils were formed in low lying areas subject to frequent overflow or areas with perched water tables which supported *Carex*, *Juncus*, swamp grasses, and willow species, and vary from a meter to several meters in depth. The areas vary in size from a few hectares to as much as 1000 ha. The larger areas, when drained, are cultured to high income per/ha crops requiring special equipment and management techniques. Smaller areas are usually integrated into conventional cultural patterns common to the area. Although many areas are tile drained, they are too wet in the spring for wheat production so they are usually planted to soybeans or corn. Weeds become a serious problem when corn and soybeans are grown continuously under these conditions. Yields of grain crops are often below average due to weed competition, late planting due to wet conditions, and early frosts resulting from cold air drainage. The growing season is shortened as much as three weeks compared to adjacent well drained areas which are only a few meters higher.

Owners and operators of smaller areas of muck continue to use these areas for production of corn and soybeans. However, forages may be a more profitable alternative on these muck soils if adapted grasses and legumes are selected. Establishment of legumes on such soils pose problems due to excess water, wind erosion during establishment, and frost heaving.

Preliminary small plot test trials in 1968-69 with 16 grasses and legumes at the Pinney Purdue Agricultural Center at Wanatah demonstrated that several cool-season grasses but only one legume, birdsfoot trefoil (*Lotus corniculatus L.*) are productive under these conditions.

Literature Review

Birdsfoot trefoil, (*Lotus corniculatus* L.), a low growing warm-season legume with a semi-branching taproot, has been found to be very competitive with grass species of comparable height. Test trials over several years at the Miller Purdue Agricultural Center at Upland showed it to be compatible with Kentucky bluegrass, (*Poa pratensis* L.), where it provides forage in the warm part of the season and also provides nitrogen for the bluegrass during the cool spring and late reported to grow in wet soils, after successful establishment, in many dairy producing areas in the Northeast (1). Although not as high yielding as alfalfa, it is very palatable, high in protein, and thus a very desirable species to include in a forage mixture (2).

Birdsfoot trefoil is a difficult species to establish since the seed is small, germination is slow, and seedlings are weak. Very often competition from other species prevents its successful establishment. Therefore it cannot become established unless competition is reduced or eliminated by frequently clipping or use of herbicide (4). This species will establish and thrive on droughty soils, when protected by clipping. Thick stands have established along many roadsides in southern Indiana. Birdsfoot trefoil is a prolific seed producer under proper management and will reseed itself and spread to adjacent areas.

Methods and Materials

The continued struggle with weed competition, late planting and low grain yields on a 48 ha area along with a need for more forage for the cow herd at Pinney Purdue Agricultural Center prompted the authors to suggest an alternative program for this muck area.

Journal Paper No. 6535. Purdue Univ. Agricultural Experiment Station.

The results of a grass-legume test plot trial in the muck area showed that birdsfoot trefoil (*Lotus corniculatus* L.), is the only legume that can survive where the water table averages 1 m below the soil surface and its temperature year-round is 15-17°C. Several grass species including: orchardgrass (*Dactylis glomerata* L.), tall fescue (*Festuca arundenacea* Schreb.), reed canarygrass (*Phalaris arundinacea* L.), and Kentucky bluegrass (*Poa pratensis* L.), also show promise.

In the spring of 1971 birdsfoot trefoil was seeded at a rate of 4 kg/ha in early May on a 4 ha area on a better drained portion of the field. A very good stand of 75-200 plants per square meter emerged by mid-May. However, it was obvious that these tiny seedlings 2-4 cm tall would be shaded out by rapidly growing broad-leaved weed species which had attained a height of 10 cm. Therefore, the area was sprayed with 2,4-DB which successfully eliminated most of the broad-leaved weeds. A 5-week dry period followed which eliminated about half of the trefoil seedlings and another weed population emerged. During the remainder of that season, the area was clipped frequently to keep the weed stubble to 10 cm. In mid-August the area was overseeded with 12 kg/ha of Kentucky bluegrass which emerged by mid-September.

The weed stubble and trefoil stand prevented any surface wind erosion which is frequent on open muck areas during winter months. In fact, over the past 20 years, 30-40 cm of soil has been lost from this fall when birdsfoot trefoil is dormant (3). Birdsfoot trefoil has been area. These losses were most severe following soybeans.

By the spring of 1973 the original seeding of trefoil and bluegrass was established with trefoil roots penetrating to depths of 20 cm (Figure 1). Moderate grazing was encouraged during the spring; however, the area remained idle through that summer. By fall, bluegrass competition and lodging of larger trefoil plants further reduced the trefoil stand. This could have been prevented by clipping or grazing during the summer. Thus, overprotection during establishing can be detrimental.

In the spring of 1972, a second area of 4 ha was seeded with 4 kg trefoil and 10 kg of bluegrass per ha. However, this stand was lost due to a dry spring and subsequent wind erosion. In late August, a 12 ha area was seeded with bluegrass and trefoil at 8 and 4 kg/ha respectively and overseeded with 9 kg/ha of annual ryegrass (*Lolium multiflorum* Lam.). The ryegrass was needed for establishing a quick cover to reduce the probability of wind erosion. In the spring of 1973 the second seeded area lost the year before was again seeded with trefoil and bluegrass in the residue of weed stubble left from the previous years. In only the first seeding of 1971 was birdsfoot trefoil seeded first and independent of later grass seedings.

The success of these establishments will be reported in the results. The remaining 20 ha in the muck area was seeded to trefoil and bluegrass in late summer of 1973. Thus the entire muck area once subject to many weed problems, wind erosion, low cash crop yields, along with planting and harvesting problems in spring and fall now is a lush meadow of bluegrass and trefoil. It now provides more spring forage than can be effectively managed with the present animal numbers available.

Results and Discussion

Only preliminary evaluations were made of the first planting in 1971 since it was an exploratory study. The vigor of two year old trefoil plants is shown in Figure 1 and illustrates the adaptation of this species in muck soils in competition with bluegrass.

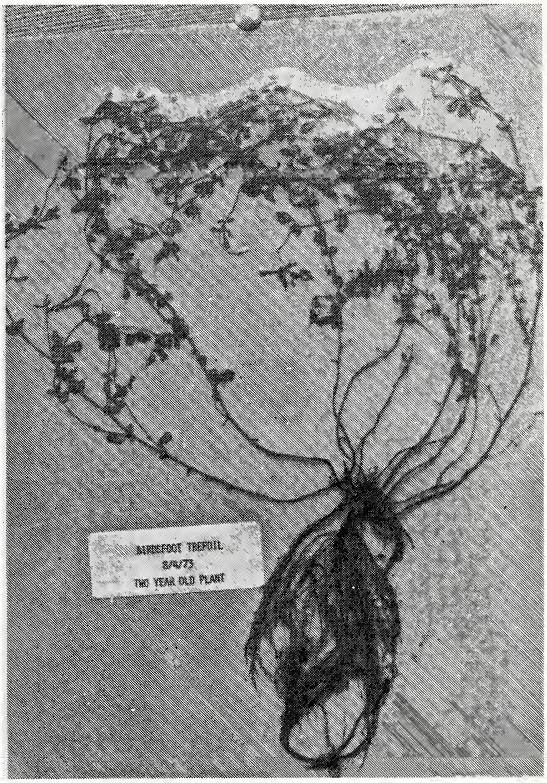

FIGURE 1. *A two year old birdsfoot trefoil plant taken from a dense stand of bluegrass. Both top and root development in these muck soils demonstrate capability to establish and compete successfully.*

The trefoil-bluegrass seedling population of the 12 ha area seeded in the fall of 1972 was extremely variable. Three m^2 quadrats were located in a line from the spoil bank ridge of a drainage ditch in this area, extending into the field at 30 m intervals and designated as replication 1, 2 and 3. In June 1973, seedling population on the well-drained spoil bank numbered 16. Over the summer, six seedlings were lost. Replications 2 and 3 extended into a more poorly drained area with severe competition from ryegrass had only 1 and 3 trefoil plants per m^2, respectively. By September, all of these seedlings were lost from shading competition. However, a good stand of Kentucky bluegrass with scattered trefoil plants was established over the area on better drained areas of this field.

The second 4 ha area reseeded the second time in the spring of 1973 was studied in more detail. This area from north to south in general decreases in desirability for seedling establishment due to wetness. Six areas 20 x 50 cm. (.1 m^2) were located north to south in the area. Seedling counts were initiated in July and made monthly through November (Table 1).

The trefoil stand on the better drained area to the north supported a greater number of seedlings. The vegetation was clipped as needed during the summer to 10 cm to eliminate weed competition and reduce shading by the grass stand.

Birdsfoot trefoil seedlings in replication 5, a depressional area to the south, were lost early and stands in all replications were reduced except in replication 6 which increased. Replication 6, the farthest south, was located on a slight rise near the first field seeded in 1971. Total population dropped from 55 to 21 over the summer which shows that by November there still was an average 120 plants per m^2. This represents good establishment in view of competition from bluegrass, a vigorous competitor on muck, and weeds.

Due to excessive moisture, very little grazing was possible the following spring except on the first 4 ha area seeded in 1971. As a result, bluegrass in all areas grew to a height of 25 cm before it could be grazed or clipped. Shading competition resulted in a further reduction in birdsfoot trefoil population. In the last area seeded during the late summer of 1973, trefoil seedlings were sparse but they did establish in better drained areas of that field.

All fields were observed again in August 1976, (5, 4, and 3 years after seeding) and in all fields a solid stand of bluegrass was present, except in two small areas where ponding was frequent. Birdsfoot trefoil populations varied but flowering plants were present in all fields and plants in ungrazed areas produced seed. Non-grazed areas over all fields occurred on dung deposits and *Juncus* culms in ponded areas. Heavy seed production of birdsfoot trefoil was noted in these culms of *Juncus* which invaded and now thrive in depressions where water frequently stands, (Figure 2).

The greatest enemy for increasing trefoil population after establishment appears to be competition from bluegrass which results from lack of aggressive management practices. Low grazing pressure early in the spring due to lack of numbers of animals or wet field conditions prevented grazing bluegrass to a height of 10 cm which is necessary to maintain good stands. This past season the area was heavily grazed during late April and early May due to unusually dry conditions and consequently 3-4 trefoil plants were present per m^2 in the first three areas seeded, (Figure 3).

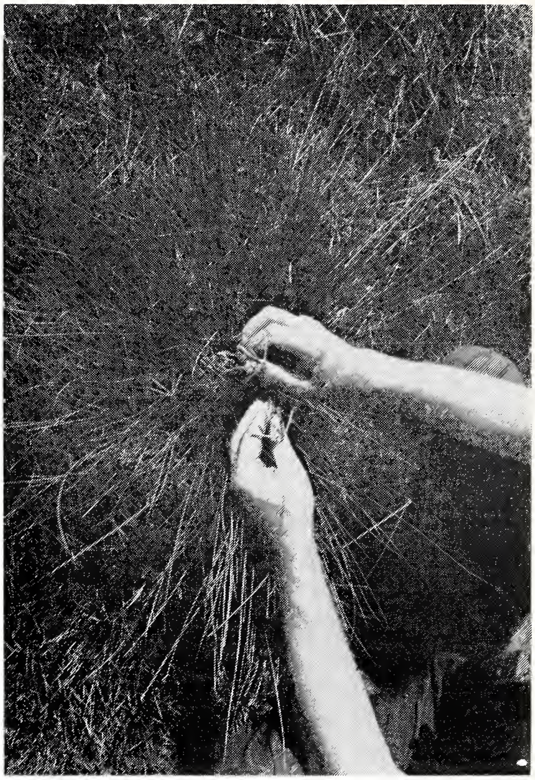

FIGURE 2. *Healthy birdsfoot trefoil plants surviving among culms of unpalatable juncus which protects them from grazing in ponded areas. These protested plants provide a continuous seed source for these areas.*

Increasing animal numbers and subdividing the entire muck area into paddocks of 4 to 5 ha will permit heavier grazing and the excess forage in ungrazed paddocks can be harvested as hay or silage. This will have a beneficial effect on increasing trefoil population.

The change of this muck area cultural practices from cash crops to a grass-legume mixture has been well accepted by the farm manager. If a problem now exists it is an over supply of forage in the spring which tends to decrease the birdsfoot trefoil population in the pastures. Further studies, to include intensive clipping of bluegrass in early spring and summer, should be initiative to determine if birdsfoot population could be appreciably increased.

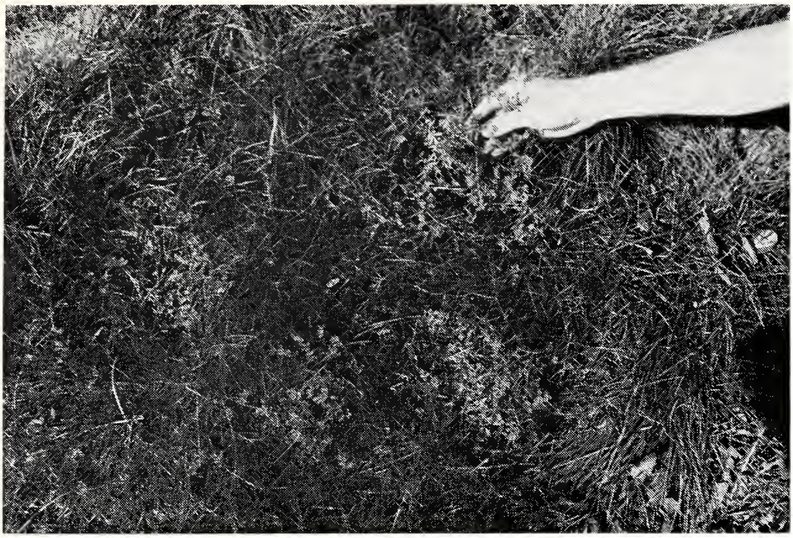

FIGURE 3. *Heavy grazing, especially in early spring, is a benefit for successful competition of birdsfoot plants.*

Conclusion

A Kentucky bluegrass-birdsfoot trefoil mixture can be successfully established on muck soils with a capability of providing forage or hay equivalent to 12 tons per ha where root systems of both species reach a permanent water table.

This study shows that birdsfoot trefoil will persist in association with bluegrass on muck soils if properly grazed. Numerous trefoil plants appear to survive among the non-palatable *Juncus* culms and in isolated ungrazed clumps of bluegrass resulting from dung or urine deposits. These trefoil plants are able to mature, producing seed to continuously re-establish the birdsfoot trefoil.

The shift from cash grain crops to a birdsfoot trefoil-bluegrass mixture on these muck soils eliminates many weed problems, concern for soil tillage at planting, wind erosion, harvesting in wet conditions, and low crop yields due to early frosts in these low lying muck areas. In addition, the high yields of high quality forage can be very profitably utilized to feed sheep, beef or dairy cattle.

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ENGINEERING

Chairman: Aldo Giorgini, School of Civil Engineering
Purdue University, Lafayette, IN 47907

Chairman-Elect: Milton E. Harr, School of Civil Engineering
Purdue University, Lafayette, IN 47907

ABSTRACTS

New Direction in Environmental Systems Planning: Experience of the Maumee River Basin Level-B Planning. Prasanta Das, School of Civil Engineering, Purdue University, West Lafayette, IN. 47907.——The "principles and standards" for water and related land resources planning prepared by Water Resources Council and adopted by Congress on September 10, 1973, identify two major objectives in such planning: (i) enhancement of national economic development by increasing the value of the nation's output of goods and services, and improving national economic efficiency; (ii) enhancement of the quality of the environment by the management, conservation, preservation, creation, restoration, or improvement of the quality of certain natural resources and ecological systems. The Maumee River Basin Level-B study is structured under this new approach in order to identify and evaluate all the major water and related land resources problems. A systems methodology is utilized in formulating and evaluating the impact of this planning on to the economic development and environmental qualities of the Basin. In particular, multiple objectives related to the above two goals are treated in noncommensurable terms for trade-off analysis between economic efficiency and environmental qualities.

Bose-Einstein Statistics and Short Time-Increment Rainfall Process. A. Ramachandra Rao, School of Civil Engineering, Purdue University, West Lafayette, IN. 47907.——Models of short time-increment rainfall process are needed in urban drainage design. Rainfall depths measured at time intervals of an hour or less constitute the short time-increment rainfall process. Although several models exist for characterizing the total rainfall, very few of these deal with the statistics of the rainfall distribution within the storm. The present paper deals with a model for the distribution of rainfall within the storm as well as the total rainfall.

The model is applied to the 5 min. rainfall data from Chicago. Rainfall data from 194 storms measured during the period 1913-1947 were used in the analysis. The parameter estimation and the validation of the model are discussed. The model is demonstrated to be a valid and accurate model to characterize the statistics of short time increment rainfall process.

The Laminar Two-Dimensional Plume in a Horizontal Magnetic Field. Donald D. Gray, School of Civil Engineering, Purdue University, West

Lafayette, IN. 47907.——The dynamics of a buoyant plume rising above a horizontal line heat source in a transverse, horizontal magnetic field is investigated. Similarity is shown to occur when the magnetic field strength varies as the -2/5 power of vertical distance from the source. The plume depends on two parameters—the Prandtl number (Pr) and the Lykoudis number (Z_L). Families of exact closed form solutions are derived for $Pr = 5/9$ and $Pr \geqslant 2$. A family of numerical integrations for $Pr = 0.01$ (typical of liquid metals) is also reported. An approximate closed form solution valid for low Pr and high Z_L is presented. Possible experimental tests of the theory are proposed.

From Ferris Wheel to Bridge. ALDO GIORGINI, Purdue University, West Lafayette, IN. 47907.——The 1893 World's Columbian Exhibition in Chicago, commemorating the fourth centenary of the discovery of America, should have featured a "proctor steel tower" which should have stood 111 feet taller than the Eiffel Tower in Paris. Mainly for political reasons, the tower was never built, but in its place its designer, the young American engineer George W. Gale Ferris (1859-1896) built the first Ferris Wheel, a 250 feet diameter wheel with 36 cars of 60 people capacity per car. The Ferris Wheel was featured again in the 1904 World's Exhibition in St. Louis. After that it was sold as scrap metal. Mr. Dunn, of Dunnville (now Dunns), Indiana, bought the metal to build a bridge (now Dunns Bridge) across the Kankakee River. The bridge is still extant, in sound shape, but no longer in use.

ENTOMOLOGY

Chairman: Virgil R. Knapp, Indiana Department of Natural Resources,
Room 613, State Office Building, Indianapolis, IN 46204

Chairman-Elect: Jack R. Munsee, Department of Life Sciences
Indiana State University, Terre Haute, IN 47809

ABSTRACTS

Cereal Leaf Beetle Parasite Program in Indiana. John J. Favinger, Indiana Department of Natural Resources, Indianapolis, Indiana 46204. ——Four hymenopterous parasites of cereal leaf beetle have been released in most Indiana counties where sufficient C.L.B. populations exist to warrant the introduction of biological controls. A mymarid egg parasite *Anaphes flavipes* (Forester) has since been recovered from fifteen counties. Two ichneumonid egg parasites, *Diaparsis n. sp.* and *Lemophagus curtus* (Fomes) have been recovered from two and three counties respectively. A eulophid egg parasite *Tetrastichus julis* (Walker) had been recovered in six counties previous to 1976 but in eighteen additional counties during June 1976.

A Distributional Survey of the Trichoptera Fauna of Delaware County, Indiana. William Tozer and Steven Newhouse, Department of Biology, Ball State University, Muncie, IN 47306.——A faunal survey representing eleven families, twenty-eight genera of Trichoptera (caddisflies) of Delaware County, Indiana during 1974-1976 is presented. Twenty-nine of fifty-five species of caddisflies collected during this study are new distributional records for Indiana. Most of the species presented belong to the families Hydropsychidae, Leptoceridae and Hydroptilidae. This list is not an exhaustively complete survey of the Delaware County region; rather, it is intended to provide stimulation for additional work of this nature.

Studies on the Reproductive Biology of *Meteorus leviventris* (Wesmael) (Hymenoptera: Braconidae). David Thomas, 464 5th Street, Madras, Oregon 97741, and R. B. Schoenbohm, Department of Entomology, Purdue University, West Lafayette, IN 47907.——The black cutworm parasite, *Meteorus leviventris*, exhibits arrhenotokous parthenogenesis; that is, females are produced from fertilized eggs, while males develop from unfertilized eggs. The daily and total egg deposition in black cutworm hosts was compared between virgin and mated parasites. It was thought that insemination might alter the females rate of oviposition; however, no significant difference was found in the daily and total egg deposition of the two female groups. Combined results of the two groups averaged 15.5 eggs oviposited per day, and 97.4 oviposited in a life time. Reproductive morphology was also studied.

A Rearing Procedure for *Meteorus leviventris* (Wesmael) (Hymenoptera: Braconidae), a Parasite of the Black Cutworm. R. B. Schoenbohm, and F. T. Turpin, Department of Entomology, Purdue University, West Lafayette, IN 47907.——*Meteorus leviventris* was the most common parasite found infesting black cutworm larvae collected in Indiana in 1974, 1975, and 1976. Parasite adults reared from black cutworm larvae collected in 1975 were used to establish a colony which is now 15 months old, or ca. 30 generations from wild. Laboratory reared black cutworm larvae are used for colony hosts. An average of ca. 200 adult female parasites are produced per day by the colony.

A Population Study of *Cicindela sexguttata*, the six-spotted tiger beetle (Coleoptera: Cicindelidae). C. BARRY KNISLEY, Dept. of Biology, Franklin College, Franklin, Indiana 46131.——A population of *C. sexguttata* was studied during the spring and early summer of 1975 and 1976 in an oak-hickory forest in Johnson County, Indiana. Census, mark-recapture, and observation were used to determine the effects of season, temperature, sunlight, and other factors on abundance, activity, and distribution of adult beetles. Most of the studies were restricted to a dirt road which ran through the woods since preliminary studies showed that beetles were most numerous here. Adults first appeared in early April, were most abundant from late April to early June, and began to disappear in mid June. Activity and numbers collected were significantly correlated with ground and air temperatures. Beetles were present in a variety of microhabitats of the forest, but were usually restricted to sunny areas. Changes in their distribution pattern within the habitat were correlated with changes in sunlight distribution. Through early May beetles were scattered somewhat evenly along the dirt road as were the patches of sunlight, but, as trees leafed out the beetles became aggregated and restricted to the limited sun patches. Other factors, such as topography, soil characteristics, and prey distribution seemed of little significance in influencing distribution. Recapture data indicated that movement of beetles along the trail was typically limited to distances of less than 100 meters. Observations on feeding habits revealed that ants were the predominate prey although a wide variety of other insects were taken. Mating was observed frequently and was most common during late May.

The Life and Work of Thomas Say. B. ELWOOD MONTGOMERY, 906 North Chauncey Avenue, West Lafayette, Indiana 47906.——Adapted from an address, "The Life and Times of Thomas Say" presented at the Spring meeting of the Academy, New Harmony, Indiana, April 23, 1976.

In 1976 we may celebrate the Sesquicentennial of Science in Indiana as well as the National Bicentennial. The Sesquicentennial commemorates the arrival of Thomas Say and other scientists at the Owen Community at New Harmony in January, 1826. Although not immediately evident all of the scientists who came to New Harmony in 1826 contributed to the attainment of American Independence.

It should be evident to everyone that 1776 marked only the beginning of the struggle for independence and that this struggle continued for many years. In fact, The War of 1812 is frequently called the Second War of Independence and the contest for control in the western areas—the upper Mississippi Valley and the far Northwest Territory —entended into the 1820's.

The colonial status was, perhaps, more slowly removed in the cultural fields, especially in the Natural Sciences, than in the political area. Geological and Biological exploration and study was long carried on in this country by visiting European students, or the studies were made and published in Europe based upon materials sent from America.

Of course, some study of Natural Science was started fairly early in America and a limited amount of publication had taken place by the time of the Revolution. This indigenous study continued to develop and had reached at least a moderate bloom at the time of the migration of the scientists to New Harmony. Much of the development had taken place in Philadelphia; all of the scientists who came in 1826 from Philadelphia to Indiana had been very active in scientific research and publication. The departure of so many of the most active workers (Maclure, Say, Lesueur, Troost) appeared to deprive Philadelphia of its leadership as a center of scientific work in this country.

No one contributed to the final attainment of independence in more areas than Thomas Say. He served in the Pennsylvania Militia in the War of 1812, and was the naturalist in two expeditions made by the army into the West—one to the Rocky Mountains and the other to the Dakota-Minnesota-Canada area, in 1819-1820 and 1823 respectively. Previous to these expeditions he had explored extensively in the Atlantic coastal areas—from Philadelphia through New Jersey to Egg Harbor (more than once), to the outer shore of Maryland and to Georgia and Florida. After coming to New Harmony he made one collecting trip of several months (chiefly for shells?) through Ohio and Kentucky and went to Mexico over one winter.

As the fauna was almost unknown the most important work in Biology at that time was the discovery and description of new species. This Say did on a very extensive scale. He published the first paper in America on fossil invertebrates. He seems to have studied almost every group of animals, describing thousands of insects of almost all orders, hundreds of Mollusca, many Crustacea, and a few to many species in each of several other groups—jellyfish, earthworms, leeches, frogs, snakes, birds and mammals.

On the two western expeditions he studied the Indians; he compiled vocabularies of some of the western tribes and described their habits and life; most of the accounts of parleys with the Indian groups included in the Reports of these Expeditions appear to have either been written by Say or based upon his notes.

Evaluation of Insecticides for Adult Western Corn Rootworm Control. David M. Leva, Purdue University, West Lafayette, Indiana 47906. ——Insecticides were evaluated as potential population suppression agents in a Western Corn Rootworm, *Diabrotica virgifera* (LeConte), control program. The insecticides were applied to field corn with a self propelled high-boy applicator. Insecticide treated leaves were randomly selected from treated plots, and used in a bio-assay with Western corn rootworm adults. Contact mortality data were recorded and the time period the various insecticides maintained at least 50% mortality were calculated. Results indicate that Sevin-4-Oil provided more than 80% mortality for 4 weeks, other compounds had an effective life of 4 to 7 days. This time interval of 4 to 7 days may be long enough for protection during corn silking and pollination. However, much longer control is needed if an adulticide is to be an effective Western Corn Rootworm population suppression agent.

Seasonal patterns of adult emergence and flight of the western corn rootworm, *Diabrotica virgifera*. GORDON VANWOERKOM.——Seasonal patterns of adult emergence were determined by placing 6 ft x 6 ft x 5 ft screen cages over corn planted at four different planting dates. Seasonal flight patterns were determined using two types of sticky traps: one quart cylindrical cartons placed at ear level and gallon cylindrical cartons placed at heights of 10, 15, 20, and 25 feet. Beetles emerging in cages and caught on sticky traps were counted and sexed every 48 hours. Differences in numbers emerging among planting dates were noted, and sex ratios of emerging beetles were compared to sex ratios of beetles caught on sticky traps. Results showed that 80% of the beetles caught throughout the season on sticky traps 10 feet and higher were females while at ear level 80% of the beetles captured were males. Adult emergence began on July 8 with a high prcentage of males. After the first two weeks the number of females emerging increased significantly.

Horned oak gall, *Callirhytis punctata* (O.S.) on pin oak in LaPorte Co., Ind. R. B. CUMMINGS, Department of Natural Resources, Indiana.——Most insect galls on plants are innocuous. Gouty & Horned oak galls caused by this genus of Cynipid wasps are considered to be economically important.

Fourteen pin oaks planted along one mile of Indiana two were studied in 1975 and 1976.

Based on the age of branches at the site of galls, the first infestation of these trees was about ten years ago.

Six trees without galls averaged 16.9 inches diameter at breast height. Three trees which were heavily infested by horned oak gall averaged 14.7 inches D.B.H. The heavy infestations caused a 13% loss of diameter growth within a period of ten years.

Insects and Other Arthropods of Economic Importance in Indiana During 1976.[1]

ROBERT W. MEYER, Department of Entomology, Purdue University
West Lafayette, Indiana 47906

Abstract

The abundance and economic impact of selected arthropods responsible for crop losses, annoyance to man and animals, destruction of food and fiber products as well as the abundance and activity of selected entomological parasites and predators of importance in their control in Indiana during 1976 are discussed.

Introduction

As a prelude to the discussion of insect activity, the more important meteorological influence on both invertebrate and plant life are reviewed. January was a cold month, February and March averaged 7° F. above normal, and temperatures fell through April to below average levels where they remained through much of the summer. The early warm months were interrupted by frosts, including a low of 9° on 17 March, 17° on 8 April and 28° on 8 May. These damaged some wheat, apples and peaches, but had little effect on corn and soybeans. The northern counties had good snow cover until 8 February, and snow fell over much of the state near the Ides of March, in advance of the 17 March freeze. There were a few local frosts early in October, but the big freeze of the fall occurred on 18 October.

Rainfall was short through most of the first 9 months of the year, especially in the southern third of the state. This facilitated planting, and by 28 May, 97% of the corn was planted, in contrast to 70% during average years. By the same time 80% of the soybeans were planted; in normal years that figure is 35%. In spite of the early planting, however, the cool summer so slowed development that harvesting was little earlier than usual. And though the rainfall was short, enough fell at the right time to produce excellent yields of both corn and soybeans.

Corn and Small Grains

Three criteria indicate that the western corn rootworm (*Diabrotica virgifera* LeConte) was more abundant this year than last. In a survey conducted in July adults were seen in 77% of the fields visited (1975:-59%) in the northern fourth of the state, in 22% of the remainder of the northern half (1975:14%). Secondly, it outnumbered the northern corn rootworm in almost all of the area north of Indianapolis. Lastly, the species invaded 15 new counties between last year and this (See Table 1 for new county records). (Table 2 contains all of the available developmental data.)

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[1] Purdue University Agricultural Experiment Station. The following includes those who have made identifiable contributions to this summary: James Clark (Ornamentals, Japanese Beetles, parasite release and recovery data), C. Richard Edwards (Alfalfa and soybean insects), John Favinger (Ornamentals, forest insects), Philip T. Marshall (Forest insects), David L. Matthew (Extension data), James Palmer (Mexican bean beetle), Lawrence Porter (Japanese beetle), David Reed (Pheromone trap data), Richard Shade (Corn leaf aphid), Richard Schoenbohm (Black cutworm and its parasites), Donald Schuder (Ornamentals), John Sillings (Extension data), Michael Sinsko (Encephalitis), Omelio Sosa (Hessian fly), F. Tom Turpin (Corn insects), Gordon VanWoerkom (Western Corn rootworm, *Coleomegilla maculata*), M. Curt Wilson (Alfalfa insects), Alan C. York (Vegetable insects).

TABLE 1. *New State and County Records for 1976. New county records which are also new state records are followed by an asterisk.*

Organism	County
Anaphes flavipes (Főrst.)	Dearborn, Huntington
Ascosphaera apis	Carroll*
Bathyplectes anurus (Thomson)	Spencer, Dubois, Daviess
B. curculionis (Thomson)	Noble, Clay, Warren, Grant, Jay, Blackford Fayette, Clark
Diabrotica virgifera LeConte	Putnam, Vigo, Clay, Owen, Hendricks, Marion, Hancock, Morgan, Johnson, Shelby, Rush, Henry, Sullivan, Greene, Jackson
Eriococcus azaleae Comstock	Marion
Microctonus aethiopoides Loan	LaPorte*
Popillia japonica Newman	Decatur, Scott, Union
Scaphoideus opalinus Osborn	Marion*
Tetrastichus julis (Walker)	Pulaski, White, Huntington, Montgomery, Tippecanoe, Bartholomew, Boone, Hendricks, Johnson, Morgan, Harrison, Washington, Jackson, Lawrence, Orange, Dearborn, Franklin, Jennings
Toumeyella pini (King)	Marion*

Northern corn rootworm (*D. longicornis* (Say)) apparently declined in numbers. At least adults were found in fewer fields during the July survey than last year. From north to south, by quarters of the state, they were found in 9% (1975:20%), 27 (19), 27 (27), 8 (41) of the fields. Likewise the southern corn rootworm (*D. undecimpunctata howardi* Barber) populations were depressed; they were found in only 2% (only in the southern fourth) as compared with 16% of the fields in 1975.

Pupation of overwintering larvae of the European corn borer (*Ostrinia nubilalis* (Hübner)) was virtually complete by 12 May in upright stalks in Daviess Co., and adults appeared in BL traps by mid-May over much of the state. First flight peaked between 28 May and 17 June and the second flight remained heavy over much of the state from 23 July to 19 August. There was an average of 3.1 larvae/100 stalks in mid-July, up from 1975 (0.9/100). The northeastern and southwestern corners of the state had the highest populations. The fall survey, with a similar population distribution, averaged 40 borers/100 plants, 4 fewer than average.

Damage by the corn earworm (*Heliothis zeae* (Boddie)) was observed in only 4 fields (of 189) all in the southern quarter of the state and all in late-planted corn. The corn leaf aphid (*Rhopalosiphum* *maidis* (Fitch)) according to the fall corn survey infested only 7.5% of the corn, mostly lightly and about the same as in 1975. A field of susceptible (Kentucky 27) corn of appropriate age averaged 581/stalk in 1976, as compared with 934 in 1975. Although several fields of sorghum in Vermillion Co. were noticeably infested by this species, most fields were free of them, an uncommon occurrence. The greenbug (*Schizaphis graminum* (Rondani)) was also rarely observed on this crop.

TABLE 2. *Date of first observation and/or peak population of several pest species.*

Organism	Stage	*Occurrence* First	Peak(s)	County	Data Source
Agrotis ipsilon (Hufn.)	Adult	16 Apr	2-8 Jul	Tippecan.	BL Trap
Aphis pomi DeGeer	1st instar	4 Mar	—	Vigo	Observed
Argyrotaenia velutinana (Walker)	Adult	6 Jun	mid-Jun	Knox	Pheromone
Choristoneura rosaceana (Harris)	Adult		15 Sep	Knox	Pheromone
Diabrotica longicornis (Say)	Adult	5 Jul	—	Parke	Observed
D. virgifera LeConte	Larva	11 Jun	—	Porter	Observed
	Adult	1 Jul	—	LaPorte	Observed
	Adult	—	27 Jul	Tippecan.	Sticky tr.
Epilachna varivestis Mulsant	O/wntr adult	26 May	14-21 Jun	Lawrence	Research
	Gen. 1 egg	8 Jun	5 Jul	Lawrence	Research
	Gen. 1 adult	15 Jul	2 Aug	Lawrence	Research
	Gen. 2 egg	19 Jul	5-12 Aug	Lawrence	Research
	Gen. 2 adult	19 Aug	7-12 Sep	Lawrence	Research
Grapholitha molesta (Busck)	Adult	—	22 Apr	Knox	Pheromone
Heliothis zeae (Boddie)	Adult	6 Aug	—	Porter	BL Trap
Laspeyresia pomonella (Linnaeus)	Adult	10 Jun	30 Aug	Knox	Pheromone
Ostrinia nubilalis (Hbn.)	Gen. 1 adult	16 May	31 May	Randolph	BL Trap
	Gen. 2 adult	—	4 Aug	Randolph	BL Trap
Oulemma melanopus (Linnaeus)	1st instar	10 May	—	Huntingt.	Research
	2nd instar	19 May	—	Huntingt.	Research
	3rd instar	25 May	—	Huntingt.	Research
Peridroma saucia (Hbn.)	Adult	19 Apr	9 Jul	Tippecan.	BL Trap
Philaenus spumarius (L.)	1st instar	12 Mar	—	Dubois	Observed
Pseudaletia unipuncta (Haworth)	Adult	30 Mar	24 Apr, 3 Jul	Tippecan.	BL Trap
Pyrrhalta luteola (Muller)	Egg	22 May	—	Tippecan.	Observed
	1st instar	24 May	—	Tippecan.	Observed
Reticulitermes flavipes (Kollar)	1st swarm	8 Mar	—	Vigo	Observed
Rhagoletis pomonella (Walsh)	Adult	30 Jun	mid-Jul	Knox	Pheromone
	Adult	25 Jun	—	Tippecan.	N. J. Trap
Synanthedon pictipes (Grote & Robinson)	Adult		10 Jun, 9 Sep	Knox	Pheromone

Larvae of the black cutworm (*Agrotis ipsilon* (Hufnagel)) were observed in more fields than usual. Nevertheless, although growers were encouraged to report problem fields, no more than 400 acres in the state had economic infestations. In fact, the common stalk borer (*Papaipema nebris* (Guenée)) probably occasioned more inquiries than the black cutworm. Minor but uncommon pests of corn in 1976 include: a billbug (*Sphenophorus zeae* Walsh), reported to have destroyed 20 acres in Decatur Co., a sod webworm, (probably *Crambus mutabilis* Clemens) destroyed patches of corn in Adams, Warren, Decatur and Washington counties; wireworms (unidentified), which necessitated replanting 180 acres of popcorn; and a grass thrips (*Anaphothrips obscurus* (Müller)), which seriously damaged about 3 acres of corn in Gibson Co.

The armyworm (*Pseudaletia unipuncta* (Haworth)) was the source of more telephone calls to Purdue Extension Service workers than any other insect in 1976. As many as 250 adults/week/BL trap were collected by 27 April, and by 12 May larvae had reached a half-inch in southern Indiana roadsides. By 28 May there were reported from wheat in the same area and were cutting wheat heads a week later in Sullivan Co. A 30-acre field of corn planted on turned-down rye was severely damaged in Rush Co. Calls from north-central Indiana began about 4 June, and continued through the middle of June. Most populations did not exceed 2-3 larvae/linear foot of wheat row, and didn't require treatment unless the larvae began cutting heads, which occasionally happened. BL trap collections peaked at about 1600 adults/trap/week.

Two species of aphids, the oat bird-cherry (*Rhopalosiphum padi* (Linnaeus)) and the English grain (*Macrosiphum avenae* (Fabricius)) which normally are abundant only in the southwest corner of the state, were numerous enough in small grains to attract attention as far north as the central and even northern districts. The infestations were too late in the season to do damage to the crops.

Hessian fly (*Mayetiola destructor* (Say)) remained at low levels. Of 260 fields in 48 counties surveyed, 13% were infested, only 3 of which had 10% of higher levels of infestation. The mean number of puparia/100 stems for all surveyed wheat was 0.9, the mean for cultivars resistant to Race B Hessian fly was 0.2, the mean for cultivars not resistant was 4.0.

Late instar nymphs of the chinch bug (*Blissus leucopterus* (Say)) were reported from 4 locations in Adams Co. about 15 July from corn fields next to wheat. None was economic, nor did any economic numbers show up in the fall, 1975, preferred host survey. The cereal leaf beetle (*Oulema melanopus* (Linnaeus)) rarely reached economic levels, but populations increased over 1975.

Forage Legumes and Soybeans

The number of larvae resulting from the hatch of overwintering eggs of the alfalfa weevil (*Hypera postica* (Gyllenhal)) are customarily a problem only along the Ohio River. In 1976 these eggs survived in such numbers and hatched so early that overwhelming numbers were present on very short alfalfa as far north as US 50. Insecticides were necessary so early that they were no longer effective when spring-laid eggs hatched, and a second treatment, or at least a stubble-spray, was often advised in that area.

Egg deposition started as usual in the fall of 1975. By 10 December eggs/square foot averaged 80 in the northern districts, 48 in the west central, 100 in the east central and 260 in the southern. Or, in a good stand in the southern districts, enough if all survived to supply each stem with 5 larvae. By 25 February egg counts in the southern districts had dropped to 120/square foot, indicating hatch. By 12 March the southwest corner of the state had 2.5 larvae/infested stem in alfalfa that averaged only 2.8″. A comparison over several years is instructive. In south-central Indiana, at about the level of 300 heat units (base 48°F.), the following prevailed: (year, height, larvae per infested stem); 1973, 7″, 1.7; 1974, 4.4″, 0.9; 1975, 5″, 5.7; 1976, 3.1″, 3.4. By 24 March 10% of the stems in Harrison Co. had clutches of eggs. By 2 April untreated alfalfa at 4.9″ had 5.6 larvae, and with an average of 1.5 eggs/stem, more larvae were still to come. When they hatched, even the most persistent pesticides applied to control overwintering larvae were no longer effective. And growth was insufficient to permit harvesting, so a second treatment was the only alternative.

Overwintering eggs appear to have survived in sufficient numbers as well in northern Indiana for the first time to be of importance. Treatment was necessary in most instances north of US 30. In the rest of Indiana north of Indianapolis economic infestations were uncommon although feeding was usually evident. South of Indianapolis damage was usually economic; a minimum of one treatment was necessary and 2 were needed south of US 50.

The potato leafhopper (*Empoasca fabae* (Harris)) is always a serious problem in Indiana alfalfa. However, it reached damaging proportions later than usual so that in 1976 its full impact was not felt until late August.

The Mexican bean beetle (*Epilachna varivestis* Mulsant) was more numerous on a state-wide basis in soybeans than in previous years, but peak populations usually occurred after the point at which greatest damage could have been inflicted. Except for Parke Co., this insect attacks soybeans only south of Indianapolis (One light infestation was observed in Tippecanoe Co. this year). There were reports of some damage in late June in Clay and Owen counties. Later in the year the heaviest infestations occurred in Ripley Co., with smaller areas in Daviess Co., and treated fields were observed in Morgan Co.

Fruits and Vegetables

The Colorado potato beetle (*Leptinotarsa decemlineata* (Say)) was much more abundant than it has been for some years, both in potatoes and occasionally in tomatoes. Both crops were attacked this year also by the potato flea beetle (*Epitrix cucumeris* (Harris)).

The imported cabbage worm (*Pieris rapae* (Linnaeus)) was more common in cole crops this year than the cabbage looper (*Trichoplusia ni* (Hübner)).

The striped cucumber beetle (*Acalymma vittata* (Fabricius)) was present in cold frames in Knox Co. by 30 April, and by 4 June was present both in Knox and Tippecanoe counties at the rate of 8-10/cucumber plant. In early September they were observed at the rate of 30-40/blossom on butternut squash in Shelby Co.

Ornamentals, Forest and Shade Trees

Gypsy moth (*Porthetria dispar* (Linnaeus)) surveys recovered no moths in 1976. As a precautionary measure, a gypsy moth parasite release program was begun this year, and the following parasites were released in the following counties: *Brachymeria intermedia* Nees—Lake, Porter, LaPorte, Starke, St. Joseph, Steuben, Martin, Lawrence. *Palexorista inconspicua* (Meigen)—Lake, Porter, LaPorte, Starke, Marshall, Elkhart, St. Joseph, Steuben, LaGrange, Martin, Lawrence. Both species are capable of establishing on species other than the gypsy moth.

The forest tent caterpillar (*Malacosoma disstria* (Hübner)) was again present in numbers along the Lawrence (SC)-Martin (SW) county line, and some mortality has occurred especially among oak trees. From 6000 acres in 1975, the area this year was extended to about 15000 acres, including an area in Owen Co. near Cuba. A reduction in the severity of the attack appears likely for 1977, except for smaller areas.

Fall webworm (*Hyphantria cunea* (Drury)) attacks were light through the state except for an area along the Porter-LaPorte Co. line, and some trees in Shakamak State Park.

Japanese beetle (*Popillia japonica* Newman) adults were first observed 18 June in Elkhart Co., earlier than usual. Adults were conspicuous in some Newton Co. soybean fields, which has not happened in some years, and they were reported destroying ornamentals in Tippecanoe Co. and other places.

Man and Animals

The following is a review of the inquiries received by Purdue Extension staff concerning household arthropod problems. For convenience synanthropic arthropods are here grouped according to their intimacy with their hosts. Of the arthropods that only accidentally invade the home spiders were still the most commonly reported, followed closely this year by Collembola, the latter at twice their usual number. Moth flies (Psychodidae) were much less frequently reported than average. Among commensals the Indian meal moth (*Plodia interpunctella* (Hübner)) was reported more often than at any time in 10 years. A cabinet beetle, *Trogoderma ornatum* (Say), occupied second place and was reported more this year than in the previous 9 years together. Of the insects that feed upon so-called non-edible properties the black carpet beetle (*Attagenus megatoma* (Fabricius)) was most often reported, followed immediately by the carpet beetle (*Anthrenus scrophulariae* (Linnaeus)). Both of these were at 10-year highs. Termites were reported an average number of times, but the carpenter ant (*Camponotus* sp.) was reported only half as frequently as usual. Among the arthropods that invade our person the clover mite (*Bryobia praetiosa* Koch) was the most frequently reported.

Of the arboviruses, 18 cases of St. Louis encephalitis and 3 of California encephalitis were recorded by mid-November, as compared with 323 cases of the St. Louis strain alone in 1975.

Beneficial Insects

An attempt was made to estimate the rate of parasitization of the alfalfa weevil by 2 species of *Bathyplectes*. During the month of May collections of alfalfa weevil larvae from all districts yielded the following rates (mean %) of parasitization by *Bathyplectes curculionis* (Thompson): the lowest rate—4%—was in the northwest district. The west central had 48, the south central had the highest—57, the southwest had 28 (one-field sample) while the rest of the state ranged between 17 and 20.

Bathyplectes anurus (Thompson) is confined to south central and southwest Indiana. In the former, in April, it occurred in 8.3% of the alfalfa weevil larvae held for rearing; in May, 1.3%. In the southwest, where it has only recently arrived, it appeared in April in 0.19%, in May in 0.4% of the hosts.

The alfalfa weevil egg parasitoid *Patasson luna* (Girault) was present in 3.5% of 801 alfalfa weevil eggs collected from the northern half of Indiana on 10-11 December 1975.

Only 23.8% of the 421 field-collected black cutworm larvae held for rearing were parasitized this year, as compared with about 60% in 1975. Of this percentage 14.3% were parasitized by *Meteorus leviventris* (Wesmael), 5.2% by the tachinid fly *Bonnetia compta* (Fallen), the remainder by other species.

Cereal leaf beetle larvae parasitized at the rate of 28% by *T. julis*, 20% by *Diaparsis* spp. and 2% by *Lemophagus curtus* Townes were released at 3 sites in each of the counties between Morgan Co. east to Union Co. inclusive and as far south as Perry Co.

The sarcophagid parsite *Sarcophaga aldrichi* Parker parasitized 30% of the forest tent caterpillar (*Malacosoma disstria* Hübner) larvae collected in the outbreak area in Lawrence Co. (SC) as of 20 July.

Adult lady beetles, *Coleomegilla maculata* DeGeer were present in most southern alfalfa fields by mid-April, and larvae were approaching maturity by mid-May. The numbers of this species observed on corn during the annual summer (July) corn survey were much higher than in previous years, 294 on 2400 stalks (96 fields), as compared with 192 in 1975, 87 in 1974. The increase was more than likely due to the large numbers of aphids that occurred earlier in the year on small grains. Of the 294, 16 were parasitized by *Perilitus coccinellae* Schrank and 3 were dead of unknown causes. A flight of this beetle was detected by sticky traps in Tippecanoe Co. between 2-4 October. A similar flight, detected by rotary trap, occurred between 27 September and 1 October in 1975.

Mosquito Diversity in St. Joseph County, Indiana (Diptera: Culicidae)[1]

D. A. SHROYER, R. F. BEACH, L. MUNSTERMANN, J. PELOQUIN,
J. L. PETERSEN, R. P. SMITH and D. B. TAYLOR
Vector Biology Laboratory, Department of Biology
University of Notre Dame, Notre Dame, Indiana 46556

Abstract

An intensive mosquito survey of St. Joseph County, Indiana, was undertaken in 1976 to provide information on mosquito diversity, distribution, and abundance within the area. Location of larval breeding sites was emphasized, supplemented by a New Jersey light-trap program and man-bait collections. Over 2000 larval sites were identified in the 500 square-mile area.

Of the 52 species of mosquito known to occur in Indiana, 35 (8 genera) are endemic to St. Joseph County. Larval sites for most species were identified within the county, and 31 species were represented in the light-trap collections.

Introduction

Until recently, all serious study of the native mosquito fauna of Indiana could be attributed to two men, the late Dr. Russell E. Siverly of Ball State University and John Hart of the Hayes Arboretum in Richmond. Siverly's publication, *Mosquitoes of Indiana* (1), is the most comprehensive source of information on the distribution of species within the state. However, only Delaware County (2) has been studied intensively enough to reveal the full complement of disease vector and non-vector species which occur in the area.

In the wake of the 1975 epidemic of St. Louis Encephalitis (SLE), many county health departments in Indiana sought to initiate mosquito control programs. Most counties began their programs with no knowledge of the potential vector species occurring in their areas. This critical information gap was generated by long-standing lack of public interest in mosquito control, apart from the individual efforts of Siverly and Hart. In Indiana, the "species sanitation" approach to mosquito control is advocated, in which only suspected vector species or major pest species are actively attacked. This is, of course, impossible unless (a) the target species are known, and (b) the larval breeding sites of the offending species are located.

In order to implement the species sanitation concept in St. Joseph County, the Vector Biology Laboratory of the University of Notre Dame undertook a large-scale mosquito survey in cooperation with the St. Joseph County Health Department. The objectives of the survey were (a) to locate every major larval breeding site in the county's approximately 500 square miles, and (b) through larval and adult sampling, obtain as much information as possible on mosquito diversity, distribution, and abundance within the county.

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[1] This investigation was supported by the St. Joseph County, Indiana, Health Department, and by NIH Research Grant No. A1-02753.

Materials and Methods

Using relatively large numbers of locally trained personnel, each square-mile section of the county was systematically and intensively surveyed for even the smallest breeding sites (e.g., tires, cans, tire ruts, catch basins etc). During May-August, 1976, each section was completely surveyed twice, which often permitted collecting both "spring" and "summer" species at the same sites. Over 2000 breeding sites were thus identified.

Aquatic populations were sampled with long-handled pint dippers or turkey-baster syringes. Late-instar larvae were identified, and, when possible, early instars in each collection were reared to identifiable age as well. Pupae were allowed to complete development and were identified as adults. Also, egg rafts were allowed to hatch, and the larvae produced were identified.

Adult mosquito populations were also sampled. Man-bait collections were made at the larval production sites. In addition, New Jersey light trap stations were established in diverse parts of the county, and daily trap samples were identified.

Results and Discussion

As a result of the intensive survey of St. Joseph County during the summer of 1976, 35 species of mosquito were found (Table 1). Larval breeding sites within the county have been identified for most of these species.

On the basis of their ubiquity and human biting activity, *Aedes vexans* (Meigen), *Aedes trivittatus* (Coquillett), *Aedes triseriatus* (Say), *Aedes stimulans* (Walker) and *Aedes canadensis canadensis*

TABLE 1. *The mosquitoes of St. Joseph County, Indiana—1976.*

- *Aedes*
  - *abserratus* (Felt and Young)
  - *aurifer* (Coquillett)
  - *canadensis canadensis* (Theobald)
  - *cinereus* Meigen
  - *dorsalis* (Meigen)
  - *excrucians* (Walker)
  - *fitchii* (Felt and Young)
  - *hendersoni* Cockerell
  - *sticticus* (Meigen)
  - *stimulans* (Walker)
  - *triseriatus* (Say)
  - *trivittatus* (Coquillett)
  - *vexans* (Meigen)
- *Anopheles*
  - *barberi* Coquillett
  - *crucians* Weidemann
  - *punctipennis* (Say)
  - *quadrimaculatus* Say.
  - *walkeri* Theobald
- *Coquillettidia perturbans* (Walker)
- *Culex*
  - *erraticus* (Dyar and Knab)
  - *pipiens pipiens* Linnaeus
  - *restuans* Theobald
  - *salinarius* Coquillett
  - *tarsalis* (Coquillett)
  - *territans* Walker
- *Culiseta*
  - *inornata* (Williston)
  - *melanura* (Coquillett)
  - *morsitans dyari* Coquillett
  - *silvestris minnesotae* (Barr)
- *Orthopodomyia*
  - *alba* Baker
  - *signifera* (Coquillett)
- *Psorophora*
  - *ciliata* (Fabricius)
  - *columbiae* (Dyar and Knab)[1]
  - *ferox* (Humboldt)
- *Uranotaenia sapphirina* (Osten-Sacken)

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[1] *Psorophora columbiae* (Dyar and Knab) = *Ps. confinnis* (Lynch-Arribalzaga) (4,5).

(Theobald) are of considerable importance in St. Joseph County. *Anopheles punctipennis* (Say), *Anopheles quadrimaculatus* Say and *Culiseta inornata* (Williston) were commonly encountered, the latter species being very abundant in May.

Culex restuans Theobald and *Culex territans* Walker were exceedingly common and often locally abundant throughout 1976. *Culex pipiens pipiens* Linnaeus was not prevalent until the latter half of the mosquito season. There was no evidence of man-biting by any *Culex* species in our area, despite the status of *Cx. p. pipiens* as the presumed vector of human SLE in Indiana. Over a period of several years, Shroyer and Siverly (unpublished observations) failed to observe man-biting by *Cx. p. pipiens* in the state.

Though larval sampling was emphasized, 31 species and 8 genera were represented in 19,468 mosquitoes identified in the light trap program. As shown in Table 2, *Ae. vexans* was the most commonly captured species. While larval survey indicated that *Ae. vexans* and the *Culex* species were abundant, relative abundance of the species listed cannot be extrapolated from light-trap data due to the highly biased nature of this sampling method.

Of all adults captured in New Jersey light traps, 74% were females. The impracticality of routine preparation of male genitalia for identification accounts for part of the excess of females. Yet some common species with readily and reliably identifiable males (e.g. *Ae. vexans*, *An.*

TABLE 2. *Summary of New Jersey light trap collections, 1976.*

Species	No. of females	No. of males	Total no. collected	% of total
Aedes vexans	6,888	2,492	9,380	48.2
Culex salinarius	940	65	1,005	32.1
Culex restuans	239	87	326	
Culex pipiens pipiens	215	195	410	
Mixed *Cx. restuans/pipiens*	2,585	198	2,783	
Unidentifiable *Culex*	106	1,613	1,719	
Aedes sticticus	1,554	38	1,592	8.2
Anopheles punctipennis	428	41	469	2.4
Anopheles quadrimaculatus	292	38	330	1.7
Culex territans	245	61	306	1.6
Coquillettidia perturbans	266	18	284	1.5
Aedes stimulans	271	0	271	1.4
Uranotaenia sapphirina	86	117	203	1.0
Anopheles walkeri	108	0	108	0.6
Infrequently collected species[1]	198	84	282	1.4
TOTAL	14,421	5,047	19,468	

[1] *Aedes triseriatus, Psorophora ciliata, Aedes excrucians, Orthopodomyia signifera/alba, Aedes trivittatus, Aedes hendersoni, Aedes canadensis canadensis, Culiseta inornata, Culex tarsalis, Aedes abserratus, Aedes dorsalis, Anopheles erucians, Culex erraticus, Aedes cinereus, Anopheles barberi, Culiseta melanura, Culiseta morsitans dyari, Psorophora ferox, Psorophora columbiae.*

punctipennis, *Cx. territans*, and *Coquillettidia perturbans* (Walker)) also show a real paucity of males. This phenomenon could have several biological explanations, all of which remain unexamined. Bidlingmayer (3) reported similar data from New Jersey light traps in Florida.

During his two-decade study of the mosquito fauna of Delaware County, Indiana, Siverly (1, 2) identified a total of 32 species in the 400-square-mile area. The number of species in Delaware County compares favorably with the number found in the somewhat larger St. Joseph County. Prior to the present study, the mosquito fauna of St. Joseph County had not been seriously studied and *Aedes hendersoni* Cockerell (1) was the only resident species reported in the literature. Possibly, a few additional species will be discovered in St. Joseph County in the future.

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New Indiana Records of Aphids (Homoptera: Aphididae)

VIRGIL R. KNAPP
Indiana Department of Natural Resources
Indianapolis, Indiana 46204

Abstract

Sixteen new records of aphids from the state are listed with annotations and hosts. Many of these species, it is believed, have been referred to previously in the literature by other investigators under general nomenclature but not by their scientific names. At least they are not suspected of being new introductions to the state.

New Indiana Records of Aphids

Unless noted, all collections were made by the author.

Amphorophora crataegi (Monell). The Four-spotted Hawthorn Aphid
Siphonophora crataegi Monell
Macrosiphum crataegi Patch
Hawthorn, Madison Co., Aug. 28, 1975

Amphorophora rhododendronia Mason
Rhododendron, Marion Co., June 11, 1976

Aphis rubifolia (Thomas)
Sipha rubifolia Thomas
Cerosipha rubifolii Winter
Raspberry, DeKalb Co., June 28, 1972

Cepegillettea betulifoliae Granovsky
Riverbirch, Marion Co., June 22, 1972

Cinara piceicola (Cholodkovsky)
Lachnus piceicola Cholodkovsky
Cinara piceicola Palmer
Tilia sp., Marion Co., Oct. 15, 1975

Drepanaphis keshenae Granovsky Hottes & Frison
Acer saccharum, Marion Co., Sept. 7, 1976

Drepanaphis sabrinae Miller
Acer saccharum, Marion Co., Sept. 7, 1976

Dactynotus gravicornis Patch
Crabapple Crataegus sp., Marion Co., June 22, 1976

Macrosiphum coweni (Hunter)
Nectarophora artemisiae Cowen
Nectarophora coweni Hunter
Macrosiphum coweni Gillette & Palmer
Radiant Crab, Gibson Co., 1974

Macrosiphum gravicornis Patch
Brachen Fern, Pulaski Co., Sept. 25, 1976

Neosymydybius annulatus (Koch)
Chaitophorus annulatus Koch
Calaphis annulata Gillette & Palmer
Birch, Allen Co., July 22, 1971

Pemphigus populi-caulis Fitch
    Coll. in Yellow Pan Trap Survey in June & July (1)
Rhopalosiphum padi (L.) (Kaltenbach)
    Aphis padi L.
    Rhopalosiphum prunifoliae (Fitch)
    Coll. in Yellow Pan Trap Survey in June & July 1975 (1)
    R. N. Meyer, 1974 (2)
Pterocomma populifoliae (Fitch)
    Aphis populifoliae Fitch
    Pterocomma populifoliae Baker
    Black Willow, White Co., May 18, 1976
Shenahweun minatus (Davis)
    Drepanaphis minutus Davis
    Acer saccharum, Sept. 7, 1976

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Observations on Periodical Cicadas (Brood XXIII) in Indiana in 1976

Frank N. Young and Ross B. Zimmerman
Department of Zoology
Indiana University, Bloomington, Indiana 47401

Brood XXIII of 13-year cicadas emerged in late May and early June, 1976 in the lower Wabash and White River valleys. Light emergences occurred before May 17, but all emergence seemed delayed by cool, rainy weather. Cicadas did not begin to call until late in May.

Twelve stations established in 1963 were checked for emergence on May 17. Cicada exuviae were found on that date only at Thomas Say's grave in New Harmony. On May 22-24 all except 2 of the 12 stations showed positive evidence of cicada emergence and adults or exuviae were collected. On June 4 all 12 stations were positive and specimens were collected or choruses recorded.

The twelve stations established are as follows: Knox County, West Fork White River, at U.S. Hgw. 150; Daviess County, West Fork of White River at U.S. 150; Gibson County, S. edge West Fork White River at U.S. 41; Gibson County, 1 mi. N. Patoka on U.S. 41; Posey County, 3 mi. N.E. New Harmony on Ind. Hgw. 68; Posey County, New Harmony, Thomas Say memorial and grave; Warrick County, 0.5 mi. west Vanada on Ind. 66-662; Warrick County, Yankeetown on Ind. 66-662; Spencer County, Richland, on Ind. 161; Warrick County, 2 mi. E. DeGonia Springs on U.S. 460; Spencer County, Little Pigeon River at U.S. 460. Additional collections were made in Sullivan and Vanderburgh Counties. Cicadas were also collected in Posey County by Gene Kritsky (Univ. of Illinois).

All of the stations listed above were checked during the emergences of Brood X (1970) and Brood XIV (1974), but no signs of cicada emergence were found at the time of emergence. In July, 1970, evidence of oviposition (flagging) was observed in Knox and Spencer Counties and emergency of Brood X was reported from Vanderburgh and Knox Counties (Young, 1971). These indications and emergences were not, however, in the immediate area of the stations indicated for Brood XXIII. Brood XIV did not overlap in any area with Brood XXIII.

A general impression from our work in 1976 is that the emergence was not as heavy as in 1963. Large choruses were not found and emergence was not in any areas as heavy as that of Brood X in many places in 1970.

Marlatt (1923) reported that periodical cicadas of Brood XXIII emerged in 1911 in Bartholomew, *Daviess*, Fayette, Floyd, *Gibson*, Jackson, Jennings, *Knox*, Montgomtery, Owen, *Posey*, Putnam, Ripley, *Spencer*, *Sullivan*, *Vanderburgh*, Vigo, and *Warrick* Counties. The counties italicized were reconfirmed in both 1963 and 1976, but no indications could be found in the other counties in 1963 or 1976, despite several searches. No reports of emergence were received from other entomologists.

In the collections made *Magicicada tredecim* (Walsh and Ripley) and *M. trecassini* (Alexander and Moore) predominated. Both were present at all the stations, but *M. tredecula* (Alexander and Moore) was not taken or observed, but probably occurred in the area. It was recorded in 1963 by Hamilton and Cleveland (1964).

Voucher specimens for the collections are in the Field Museum, Chicago.

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1975. Observations on periodical cicadas (Brood XIV) in Indiana in 1974 (Homoptera: Cicadidae). Proc. Indiana Acad. Sci. 84:289-293.

Culex Mosquito Populations in the Catch Basins of Northern St. Joseph County, Indiana[1]

Leonard E. Munstermann and George B. Craig, Jr.
Vector Biology Laboratory, Department of Biology
University of Notre Dame, Notre Dame, Indiana 46556

Abstract

In the St. Joseph County Mosquito Abatement Program larval survey of 1976, numerous *Culex* encephalitis mosquitoes were discovered in the catch basins beneath street storm drains. Subsequently, a systematic inspection of catch basins was conducted in the communities of South Bend, Mishawaka, Notre Dame, Roseland, and Osceola. Presence of catch basins was found dependent on city sewerage construction policy, e.g., South Bend did not construct them (following modern sewerage practice), while Mishawaka maintained one to four catch basins at nearly every street intersection.

Collection and identification of 2200 larvae from 150 positive sites demonstrated two points. 1) Larval populations occurred in 37 to 66 percent of the catch basins, depending on previous rainfall patterns. 2) Early in the season, *Culex restuans* was the only species usually found, but by midsummer, *Culex pipiens pipiens* constituted approximately half of the collections. Proposed control measures were insecticide treatment or elimination of catch basins.

Introduction

Extensive mosquito development in catch basins, usually located beneath the storm drains at street intersections, has been recognized as a problem for many years. As early as 1915, the 5000 catch basins of Washington, D. C., were flushed and treated with mosquito oil (8). More recently, routine treatment of catch basins with insecticides has become a common practice in established mosquito abatement programs in Illinois (5, 14), New Jersey (10), Kentucky (2), Georgia (7) and California (4, 6, 13).

In response to the Indiana encephalitis epidemic in 1975, the St. Joseph County Mosquito Abatement Program was organized under the auspices of the County Department of Public Health by the Vector Biology Laboratory at the University of Notre Dame. In the first year of operation (1976), the primary objective was to locate larval sites and determine mosquito species diversity in the county. Details of the program and findings are published in these proceedings (12). Early in the survey, a significant amount of *Culex* production in catch basins was noted; consequently, a more intensive effort was made to assess them as major breeding sites.

Methods

The initial survey indicated that production potential was dependent on the construction of the system used for disposal of storm run-off. To aid in identifying the construction types, each is described below. The general term "storm drain" will be used to include any underground

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[1] This investigation was supported by the St. Joseph County, Indiana, Health Department, and by NIH Research Grant No. AI-02753.

system for removal of rainwater from the surface. Storm drains were manifested on the surface by rectangular or circular metal gratings at street intersections, depressions in grassed areas, and in larger paved surfaces.

A. *Storm drains, direct drainage.* These drains were concrete funnels connected to pipes, 15-20 cm diam, which led 1) directly to the sewer mains located beneath the street center, or 2) to a catch basin located in the same intersection (Fig. 1).

B. *Catch basin, type I.* These were large brick basins which widened to a diameter of a meter and were one to two meters deep. An overflow pipe led to the sewer mains (Fig. 2) (7).

C. *Catch basin, type II.* These are typically concrete, cylindrical basins, 0.6 m diam, connected in series by a pipeline. Each basin had an inlet and outflow pipe, with water standing below the level of the outflow pipe (Fig. 3).

D. *Catch basin, type III.* These basins had no overflow pipes but relied on seepage through a stone or gravel base for water removal. They were usually small, 0.6 m diam, and 0.6 to 1.0 m deep (Fig. 4).

E. *Dry well.* The principle of construction was the same as the catch basin, type III, but much wider (2-3 m diam) and deeper (2-3 m). This type was built to contain run-off from parking lots and other paved areas.

Five communities in northern St. Joseph County were surveyed: Mishawaka, Notre Dame, Osceola, Roseland and South Bend. The data gathered were a) storm drain construction types, b) presence of standing water and larvae, and c) species of larvae.

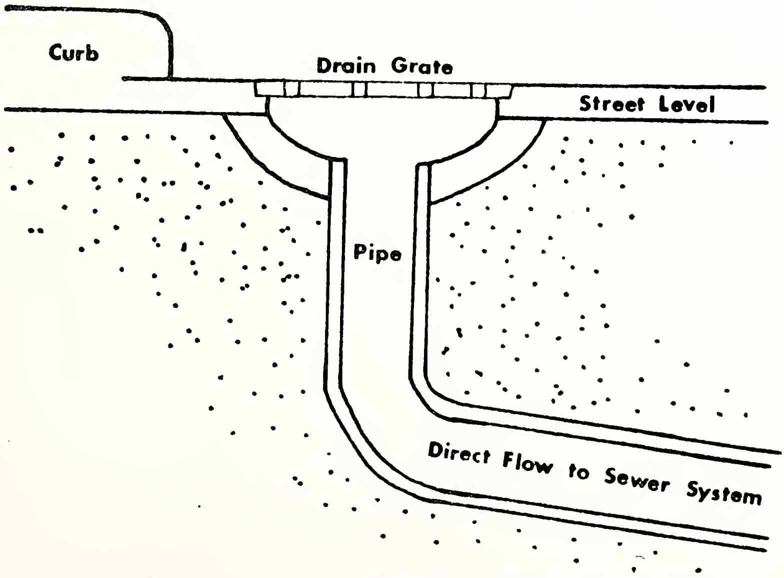

FIGURE 1. *Direct drainage storm drain, typical of South Bend storm drainage.*

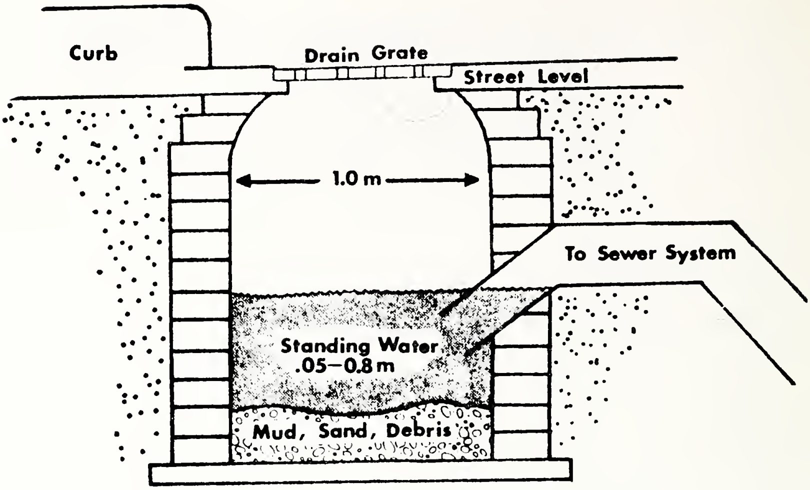
Curb
Drain Grate
Street Level
1.0 m
To Sewer System
Standing Water
.05—0.8 m
Mud, Sand, Debris

FIGURE 2. *Catch basin, type I, typical of those found below the storm drains of Mishawaka.*

Straight line, north-south (N-S) and east-west (E-W) transects were taken at the widest limits of Mishawaka and South Bend. The streets that the transects followed were

Mishawaka (N-S)—Normandy, Division, Union, and Main streets;
(E-W)—10th and 6th streets;

South Bend (N-S)—St. Louis and Fellows streets;
(E-W)—Randolf, Dubail, Indiana, and Ford streets.

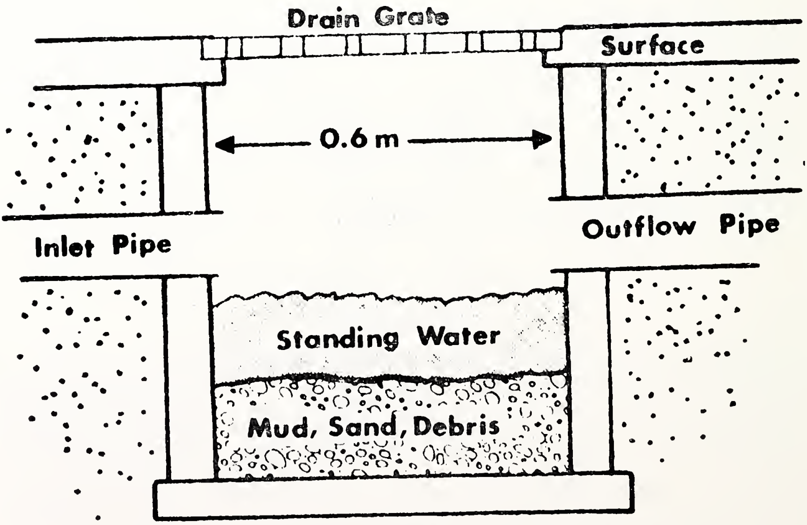
Drain Grate
Surface
0.6 m
Inlet Pipe
Outflow Pipe
Standing Water
Mud, Sand, Debris

FIGURE 3. *Catch basin, type II, used on the Notre Dame campus.*

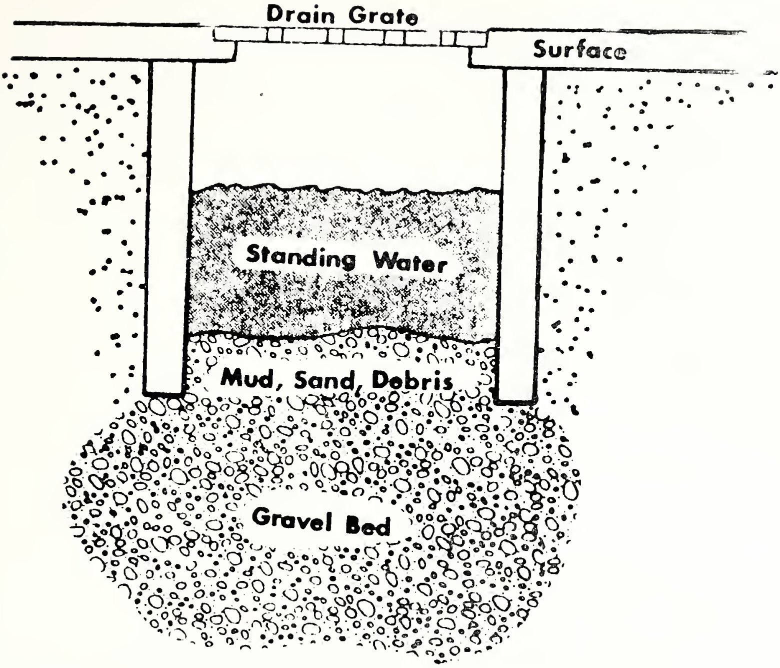

FIGURE 4. *Catch basin, type III, found along the streets of Osceola and Roseland.*

The transects in Mishawaka were repeated to detect possible seasonal and rainfall effects on population numbers. In the communities of Notre Dame, Osceola, and Roseland, nearly all of the storm drains were examined.

Whenever standing water was detected in a storm drain catch basin, the cast iron grating was removed and 6 to 10 dips were taken with a standard 0.45 liter enamel dipper. Larvae were collected into polyethylene bottles for later identification in the laboratory. Samples from dry wells and sewer mains were taken with a one-liter tin can attached to a long nylon cord.

The number of larvae found was probably underestimated for two reasons. Firstly, when the storm drain covers were lifted, debris dropping into the water caused the larvae to descend to the bottom of the basin, making collection difficult. Secondly, some catch basins were found sealed shut due to street resurfacing or were too deep to be effectively sampled.

Results and Discussion

Construction of storm drainage systems determined to a large degree the amount of standing water available for mosquito development. In South Bend, where storm run-off flowed directly into the sewer mains, few positive or potential sites were found. In the other communities, where catch basins were utilized (Table 1), most contained standing

TABLE 1. *Percent of storm drains with catch basins in five northern Indiana communities, St. Joseph County.*

Community	Storm drains	No. with catch basins	(%)	Catch basin type
South Bend	13,600[a]	27[b]	(0.2)	I
Mishawaka	2,860[b]	1,300[a]	(46)	I
Notre Dame	120	92	(77)	II
Osceola	12	12	(100)	II
Roseland	10	10	(100)	III

[a] Estimates provided by community officials.

[b] Extrapolated from transect counts.

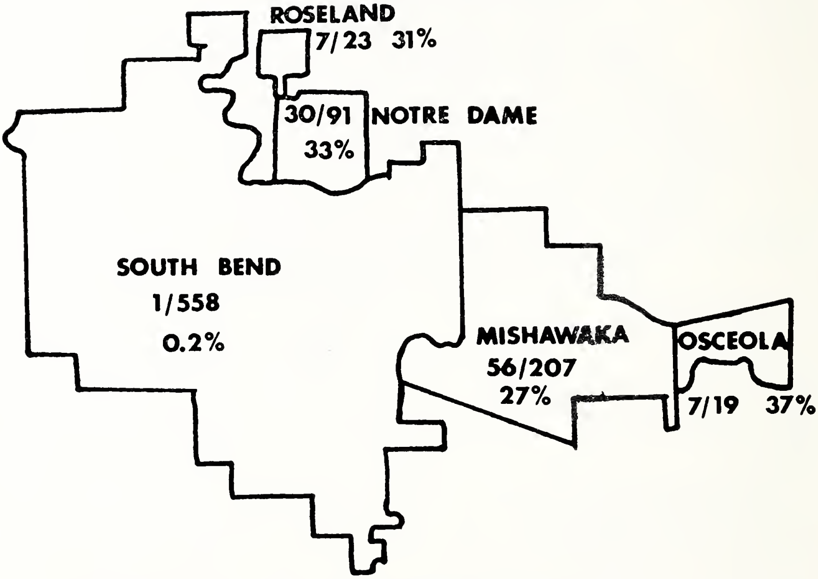

FIGURE 5. *Number of street drains and percent found with standing water and positive for* Culex *mosquito larvae in five communities of St. Joseph County, Indiana.*

water and provided excellent habitats for *Culex* mosquitoes. In Figure 5, the non-producing, direct drainage drains were included in calculating the percent positive for *Culex* larvae. However, if catch basins only were considered, 37 to 66 percent contained larvae.

In addition to catch basins, type II and III, dry wells were commonly used in Osceola and Roseland parking lots and in other paved properties. Although 19 of 25 examined contained standing water, low density larval populations were found in only two of them. Though difficulty in sampling can account for this, accumulation of oils and poisons may also prevent larval growth there.

Over 2200 larvae from 150 positive sites were collected in the five communities. All larvae were identified as *Culex pipiens pipiens* or *Cx. restuans*, with only one exception. Two *Aedes triseriatus* were taken from a catch basin on the east-west transect of Mishawaka. This probably represented an accidental introduction from an overflow of this species normal treehole habitat.

In the six-week period of collecting, a distinct trend of an increasing number of *Cx. pipiens* was noted (Table 2). When the east-west and north-south transects of Mishawaka were repeated later in July, *Cx. pipiens* had increased from 11 to 46 percent and 29 to 66 percent of the totals, respectively. This trend was noted for other larval sites of these *Culex* as well (12). In the catch basin study by Covell and Resh (3) in Louisville, Kentucky, the increase of *Cx. pipiens* began at mid-June and reached nearly 100 percent by the first week in July. If the species shift was due to a temperature threshold as they contended, then possibly the cooler seasonal temperature accounted for the later appearance of *Cx. pipiens* in St. Joseph County.

TABLE 2. *Seasonal changes in relative numbers of* Culex restuans *and* Culex p. pipiens *in catch basins in two Indiana communities, St. Joseph County, summer, 1976.*

Date Collected	Collection Area	No. Sites	No. Larvae	*Culex restuans*	(%)	*Culex pipiens*	(%)
14 June	Mishawaka (south)	9	140	137	(98)	3	(2)
6 July	Mishawaka (E-W)	24	218	193	(89)	25	(11)
12 July	Mishawaka (N-S)	26	464	331	(71)	133	(29)
20 July	Notre Dame campus	30	704	311	(44)	393	(56)
22 July[a,b]	Mishawaka (N-S)	15	89	30	(34)	59	(66)
28 July[a]	Mishawaka (E-W)	31	401	216	(54)	185	(46)

[a] Exact repeat of earlier transect.

[b] Sampled after a 8.1 cm rainfall.

The impact of heavy rains on larval populations was considerable. In the repeat of the Mishawaka (N-S) transect (Table 2), the rains reduced the positive sites from 26 to 15. The average number of larvae per positive site was reduced by 67 percent. However, because of the flushing action of run-off in the catch basins, the survival of even this number of larvae was surprising. In Savannah, Georgia, continued heavy rains virtually eliminated larval *Cx. pipiens quinquefasciatus* from catch basins, but these populations reappeared within a week after the rains stopped (1, 7).

Significance for Control Programs

Catch basins of Mishawaka and Notre Dame are major sources of *Culex restuans* and *Culex pipiens pipiens* mosquitoes. Because of the role of these species in the transmission of Eastern Equine Encephalitis anl St. Louis Encephalitis, catch basin mosquito production must be an important consideration in a control program. Two control alternatives to be considered are 1) elimination of the site, and 2) treatment with chemical insecticides.

Elimination of catch basins by conversion to a direct drainage system (Fig. 1) is a permanent solution. Many years ago, catch basins were designed solely for preventing grit and debris from entering and clogging sewerage systems. For more than 40 years, however, building of catch basins has been discouraged by sewerage engineers. This is because the more modern sewers are built to move sewage at "self-cleaning velocities" of 0.6 m per second in pipes of 30 cm or greater in diameter (9), obviating the need for catch basins.

The use of insecticides is a temporary and less satisfactory solution. Until banned, residual insecticides such as DDT had been used with success (2, 5, 6). Recently, organophosphorus compounds such as Abate (American Cyanamid, Princeton, NJ) and Dursban (Dow Chemical, Midland, MI) (11) and pyrethrin Toss-Its (WYCO International, Cleveland, OH) (2) have proved effective in catch basin larval control. These insecticides do not remain effective over longer periods and must be reapplied after every rainfall. The use of dichlorvos (DDVP, Vapona) (Shell Chemical, Fresno, CA) impregnated resin plastic strips has been successfully used against both larval and adult mosquitoes for an entire season (1, 13), though this method is much more expensive than others. In addition, special spray nozzles and vehicles have been developed and deployed for insecticide application in catch basins by several abatement districts (2, 10, 14).

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Smithistruma filitalpa W. L. Brown, an Indiana Dacetine Ant (Hymenoptera: Formicidae)

JACK R. MUNSEE, Indiana State University
Terre Haute, Indiana 47809

Abstract

Smithistruma filitalpa is a dacetine ant found in Indiana, although related forms are old world and tropical. *Strumigenys* is believed to be the ancestral genus of *Smithistruma* with the latter including forms with short mandibles, while the former have long mandibles. Small size, small nest populations, and slow movement of the ant are among factors that have caused *S. filitalpa* to be largely overlooked. Berlese funnel collections have shown that this species is not as uncommon as previously thought. Thirty-three specimens of *Smithistruma* were taken by pitfall trapping in an abandoned surface mine. On the basis of 6 workers from from these ants, which were determined by the author of the species to be *S. filitalpa*, eight additional workers were considered as belonging to the same species. Although not determined to species, 15 sexual forms and four other workers are also believed to belong to the genus *Smithistruma*. It was determined that 75-80 percent of the areas from which the ants were taken represented open or bareground situations. These findings support the supposition that *S. filitalpa* is an ant of open areas; also, its presence is probably related to the presence of collembolans upon which it feeds. The 6 specimens of *Smithistruma filitalpa* submitted for determination have been included in the Museum of Comparative Zoology collection of dacetine ants, Cornell University.

Introduction

Smithistruma filitalpa is a species of the Dacetini, a large tribe of unusual appearing ants of the subfamily Myrmicinae. The subfamily is characterized by those ants having a pedicel of two segments between the thorax and abdomen; also, they possess a sting. Dacetine ants, according to Brown (2) may be recognized as having: 1) less than six segments in the antennal funiculus; white spongy-like appendages or thin-layered lateral wings on one or both sides of the pedicel; or 2) having a flattened pear-shaped head which is narrowed anteriorly with a broad, deep occipital cleft; mandibles linear, each with two or three large apical teeth, as well as an oblique, often hidden tooth or spine at the inner basal border; or 3) having a combination of the characteristics noted in 1) and 2).

The Dacetini are widely distributed throughout the world and constitute generic complexes in Neotropical, Australasian, Ethiopian, as well as Nearctic regions (2). According to Wilson (6) the distribution of the genus *Smithistruma* includes Asia, Australia, and the New World Tropics; however, it is represented in Nearctic regions as well (2). The subgenus *Smithistruma* is almost cosmopolitan (4).

The ancestral genus of *Smithistruma* W. L. Brown, is thought to be *Strumigenys* F. Smith, which is the largest genus of the Dacetini. The *Strumigenys* complex includes 16 genera (2) one of which, *Smithistruma*, was erected by Brown in 1949. Ants of this genus are recognized as "short mandibulate" forms in contrast to the "long mandibulate" forms which are more typical of *Strumigenys*.

Morris (3) listed four species of *Strumigenys* as probably occurring in Indiana. Since these were "short mandibulate" ants they rightfully belong to *Smithistruma*. Brown (2) has recorded 15 species of this genus among the states of Indiana, Kentucky, Illinois, and Ohio. Except for one, all of the species belong to the subgenus *Smithistruma*. Illinois and Ohio are each represented by 13 of the 15 species; one was reported from Kentucky and 6 from Indiana. *Smithistruma filitalpa* was reported only from Indiana (2). The four species noted by Morris are included in the 15 recorded by Brown. Although *S. filitalpa* was cited in 1967 as one of nine ants recently recorded in the state, no reference to habitus was made (5). Figure 1 shows some of the characteristics of dacetine ants as represented by this species. Shown are the mandibles with apical teeth; pyriform head; 5-segmented antenna; and spongiform processes on the declivity of the epinotum, petiole, and postpetiole. Part of the head sculpture is shown in its upper left region.

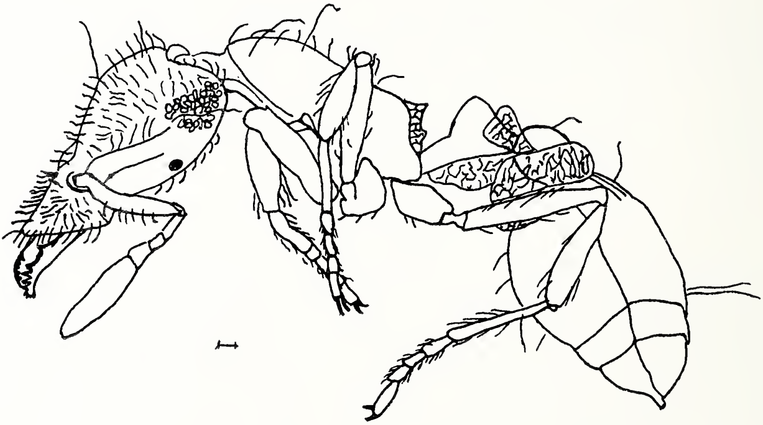

FIGURE 1. Smithistruma (S.) filitalpa *Brown showing some characteristics of dacetine ants. Partial sculpturing of head, upper left.*

Some of the biology of ants of *Smithistruma* is known, but much needs to be learned about their ecology, including that of *S. filitalpa*, according to Brown (personal communication). It has been established that *S. filitalpa* and the majority of higher dacetines are predaceous and feed chiefly upon collembolans and other soft-bodied anthropods, as noted in Brown (2) and Wilson (6). With increased collecting of species of *Smithistruma*, habitat preferences have likewise become better known. Thus, Brown notes that some species are found in open country and have been taken in the berlestates of *Andropogon* clumps. In southern Indiana he found the closely related species, *S. talpa* mainly in duff under red cedar in clearings and in old fields (personal communication).

Various factors are related to previous dearth of information about *Smithistruma filitalpa* and related species. They are small ants which move very slowly. Also, because of being light ferruginous color and tendency to feign death, they are not easily seen; in addition, colonies are small and usually well concealed (2). It was not until berlesates of habitat materials were studied that the more common occurrence of these ants was recognized. Brown's revision of the dacetine ants is the only comprehensive work on this tribe, and is therefore the primary reference of this report.

Methods

Ants belonging to *Smithistruma* referred to here were taken in pitfall traps in the spoil banks of a defunct stripmine located near Centenary, Indiana. The specimens appeared in collections made in connection with a related study on ant ecology. Originally, a worker, dealate female, and alate male were submitted to D. R. Smith, Agricultural Research Service, U.S.D.A., for identification. In the return communication, a qualified determination of *Smithistruma filitalpa* Brown was received. Closer examination of similar appearing ants showed a total of 30 additional specimens which included 17 workers, 11 females, 1 male and 1 bilateral gynandromorph. Only the workers are reported here. To firmly establish identity, six workers believed to be *Smithistruma filitalpa* were sent to Brown, after obtaining data on measurements following the method given in his revisionary work (2). Brown's reply confirmed the identification. Among the remaining workers were three that clearly were not this species; also, two unidentified workers were received from Jack Hart, Earlham College, which he had taken during studies on the Collembola, near Connersville, Indiana. One of these, along with three workers, were measured and tentatively identified before being submitted to Brown for determination. Brown noted that because of the poor condition of the ants no positive identity could be made (personal communication). Presence, arrangement, and form of clypeal and body hairs are very important diagnostic factors. The hairs are easily dislodged or matted and for this reason, Brown recommends mounting specimens on points, rather than storing in alcohol.

Generally, the method of measuring ants followed that of Brown (2), except that a stage micrometer rather than a squared ocular disc was used. Also, Brown's specimens were dry-mounted, while in this study ants were examined in alcohol or methylcellulose, the latter not recommended if specimens are to be pinned. A total of eight basic measurements were made on each of 14 worker specimens.

Results

Five of the eight measurements pertinent to this paper are given in Table 1. The five correspond to those for species of *Smithistruma* in Brown's revision (2). They represent averages compared with measurements given for Brown's holotype worker (1).

The differences for each corresponding value are small from which it may be determined, along with the description of the Brown's specimen, that the workers are the same species as the holotype.

Brown (2) suggests that *S. filitalpa* is an ant of open areas which characteristic is typical of the spoil banks from which ants in this study were taken. Vegetation consists chiefly of weeds in addition to scattered

TABLE 1. *Comparison of average measurements of 14 workers of* Smithistruma (S.) filitalpa *with corresponding measurements of the holotype.*

	Workers	Holotype
Total Length—mm	2.25	2.06
Head Length—mm	0.55	0.54
Alitrunk (WL)—mm	0.53	0.52
Cephalic Index (CI)	65.00	66.00
Mandibular Index (MI)	16.70	17.00

CI—Maximum head width/Head length X 100
MI—Mandibular length/Head length X 100

small trees. Of the four separate sites from which the specimens were taken, 75-80 percent of their areas was determined to be open or bare-ground. (Unpublished doctoral thesis.)

Like other species of the genus, *S. filitalpa* is likely to be found where collembolans are abundant. In this study, trap catches included many of these insects. Since they are a principal food source, their presence is thought to assure the presence of the ants (2).

The six specimens of *Smithistruma filitalpa* submitted for determination have been included in the Museum of Comparative Zoology collection, Cornell University, and according to Brown, "are useful towards establishing that *S. filitalpa* is a good species with its own distribution and variation" (personal communication).

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GEOLOGY AND GEOGRAPHY

Chairman: NEIL V. WEBER, Department of Earth Science
Indiana University-South Bend, South Bend, Indiana 46614

Chairman-Elect: MARK RESHKIN, Department of Public and
Environmental Affairs
Indiana University Northwest, Gary, Indiana 46408

ABSTRACTS

Modeling Predictive Indices for Indiana Corn Production: 1960-1969. NEIL V. WEBER, Indiana University at South Bend.——The purpose of this study was to quantitatively analyze the relationship (linear and quadratic) between fifteen independent variables (physical and socio-economic) and corn production in Indiana during the decade of the 1960's.

Preliminary analysis utilizing stepwise regression supported earlier research purporting that climate variables alone (i.e., motnhly growing degree days and monthly precipitation during the growing season of Indiana dent corn) explain very little of the variance in corn yield during the period in question.

Subsequent analysis adding additional variables to the regression equation (i.e., two mechanization terms, two socio-economic terms, and a slope variability term) significantly improved the predictive ability of the model.

Although the complex model described in this study is a marked improvement over the simpler climatic model, the regular pattern of residuals suggests a need for additional testing and refinement. Some of the questions to be investigated are as follows: Might some of the variables be governed by subtler areal specific terms? Will the model hold across larger time intervals? Can the slope variability term be improved and/or replaced?

Climatic Change in Southern Indiana 1898-1975. CHARLES STANBERRY, Indiana University, Bloomington, Indiana 47401.——Regression analysis is used to examine the monthly and annual temperature and precipitation data of six stations in southern Indiana for evidence of trends. Temperatures are found to increase in the period 1898-1939 and to decrease from 1940 onward. The temperature increase is greatest in the months December-February. Temperature decrease is greatest in January and February. A quadratic equation is fit to confirm the date of the onset of the downward trend. The analysis applied to precipitation data yields no clear cut trends. Some evidence is advanced to indicate a change in precipitation trends concomitant with the change in temperature trends.

Spectral analysis of the data yields few significant periodicities or quasi-periodicities in the data. The analysis does indicate the presence of persistence in the temperature data.

Cross spectral analysis shows that precipitation and temperature do not vary together periodically over any wavelengths.

Migration of a Meander of White River Near Worthington, Indiana. Robert D. Hall and Shannon L. Hall, Indiana University-Purdue University, Indianapolis, Indiana 46247.——An analysis of aerial photographs, topographic maps, and plane table surveys from 1937 through 1968 shows that a former meander of White River south of Worthington, Indiana, extended and expanded at erosion rates as high as 30 ft/yr (9 m/yr) prior to cutoff in 1968.

Maximum rates of erosion lie along radii from the meander center that are approximately normal to former flow lines of maximum velocity. A downstream shift in the location of maximum erosive power along the meander's outer bend resulted in a rapid southwesterly migration of the meander until 1966. Rates of erosion and meander migration decreased substantially from 1966 to 1968 suggesting that some of the discharge had assumed a flow path through the cutoff chute. Cutoff seems to have occurred as the meander radius to the point of impingement of the line of maximum velocity moved close to a parallelism with the trend of the chute. The former meander is now an oxbow lake.

Horton's Laws Related to the Quantitative Fluvial Geomorphology of Three Parke County Watersheds. Robert Templeton and John E. Oliver, Department of Geography and Geology, Indiana State University, Terre Haute, Indiana 47809.——Data derived from three small Parke County watersheds are analyzed using various methods of quantitative geomorphology. The derived results are examined in relation to Horton's Laws of stream numbers, stream lengths and stream area. In each case the quantitative relationships closely correspond to the theoretical models. Although the hypsometric curves derived from observed data indicate that a graded profile has not yet been attained, the drainage density of the three areas shows that the derived patterns fit well within the hypothesized range.

Hydrology and Water Quality of the Crooked Creek Watershed, Indianapolis, Indiana. Patricia A. Boaz and Robert D. Hall, Indiana University-Purdue University, Indianapolis, Indiana 46247.——A study of the hydrologic and chemical parameters of the Crooked Creek Watershed, located in the northwestern Indianapolis, Indiana, reveals the effects of rapid urbanization on this fifth-order basin. The physical characteristics of the watershed favor rapid runoff and high sediment yield in response to precipitation, particularly from the upper part of the watershed where most of the drainage net is concentrated and most of the urban development is taking place.

Hydrologic data indicate that the amount of yearly runoff has increased at an average rate of 22% since 1969. The number and magnitude of peak discharges have also increased. Monthly chemical data for the summers of 1975 and 1976 support hydrologic indications of urbanization by showing marked increases in those constituents which result from increased population. Chemical studies have also located the sources, nature, and extent of point pollution, and assessment of non-point pollution is currently underway in one subwatershed.

Images of Downtown. ROBERT B. JESSEN, Indiana University, South Bend, Indiana 46614.——As part of a study of citizen attitudes toward the downtown area of South Bend, Indiana, 1310 randomly selected respondents were asked to indicate by drawing on a map, the boundaries of what they identified as the downtown area. It was hypothesized that respondent's ability to draw the map as well as the size and boundaries of the downtown area should vary according to such factors as the respondent's age, sex, income, educational level, place of residence within the city, and uses of the downtown area. Over ninety percent of the sample were able to draw boundaries for the downtown area on the map provided. It was found that statistically significant, as well as practically significant, variations in size and boundaries of the downtown area were found for all of the aforementioned variables, except income. The greatest differences were found among persons of different educational levels and among persons who used the downtown for differing purposes.

Additionally, size and boundary variations were tested against attitudes toward the downtown. Significant differences were observed on attitudes toward security, traffic conditions and sewage provided by the downtown area, depending on the size and specific boundaries selected.

It was concluded that the term "downtown" as used in many studies is an ambiguous one. "Downtown" means different things to different persons in a spatial sense; and in turn, these spatial perceptions influence attitudes and behavior toward downtown.

A Descriptive Study of Indiana State University Faculty Settlement Patterns Over 55 Years. GROVER C. WORCESTER and BENJAMIN MOULTON, Department of Geography and Geology, Indiana State University, Terre Haute, Indiana 47809.——Between 1920 and 1975, an accelerated outward migration from Terre Haute by an expanding Indiana State University faculty was quite apparent from the interpretation of the data collected. The data consisted of addresses taken from telephone books for each of the sample years and illustrated on maps of Terre Haute. The figures were used to make percentage graphs with the two main categories being urban and rural population.

The maps showed three dominant clusters of settlement during the fifty-five-year period. Some fluctuation occurred within these clusters but their dominance remained.

The northeast quarter of Terre Haute was and still is apparently undesirable for settlement by professors.

Most significant was the increased outmigration of professors to the rural areas around Terre Haute as the years went by. The rate of outmigration is accelerated.

Except for the established areas, political Terre Haute is no longer an area generally chosen to live in by the faculty at Indiana State University.

An Approach to Automatic Well-Log Correlation. B. D. KWON, R. F. BLAKELY and A. J. RUDMAN, Indiana University, Bloomington, Indiana 47401.——Automatic (computer) correlation of well logs include how parameters of relative displacements and thickness of geologic strata affect correlation processes. These parameters are studied by operational properties of the discrete Fourier transform (DFT). It is shown that cross-correlation of power spectra can predict the thickening between two logs (stretch factor) and the cross-correlation of such stretched logs gives a relative displacement. Stretching is accomplished by interpolation.

Empirical results show that most geophysical logs are rich in low frequency components that are a source of difficulty in correlation. Hence, original data are first filtered by taking their first differences to attenuate low frequencies and smoothly enhance high frequencies. Correlation of model studies are highly effective; however, field data often need additional filtering to achieve improved results. Automatic windowing with high cut filters and statistical zonation techniques may properly select portions of the log for effective correlation.

Variability in Seven Devonian Species of *Polypora* M'Coy. JAMES F. STRATTON, Eastern Illinois University, Charleston, Illinois 61920 and ALAN S. HOROWITZ, Indiana University, Bloomington, Indiana 47401.——Evaluation of 14 measurable characters indicates that seven (number of apertures in 5 mm, branch width, number of branches in 10 mm, dissepiment width, fenestrule length, fenestrule width, number of fenestrules in 10 mm) are useful for differentiating seven species of *Polypora* that occur in the Speed Member of the North Vernon Formation and the underlying Jeffersonville Limestone of southern Indiana. Meshwork formulae are presented for the following species and subspecies: *Polypora aculeata* (Hall), *P. adnata* (Hall), *P. celsipora minima* (Hall), *P. laevinodata* (Hall), *P. quadrangularis* (Hall), *P. shumardii* Prout, and *P. transversa* (Hall). Five species are considered synonyms: *P. submutans* (Hall) and *P. blandida* Ulrich [= *P. aculeata* (Hall)], *P. laevistriata* (Hall) and *P. striatopora* (Hall) [= *P. quadrangularis* (Hall)], and *P. cultellata* (Hall) [= *P. shumardii* Prout]. *P. intermedia* Prout is considered unrecognizable. Univariate and multivariate analyses of measurements generally yield consistent results with respect to taxonomic assignments. The coefficients of variation for these polyporans are comparable to those found in other bryozoan studies.

Type III—Statistics of Extremes Analysis of Modified Mercalli Earthquake Intensities for the Eastern United States. PAUL J. HAFER and ROBERT F. BLAKELY, Indiana University, Bloomington, Indiana 47401.——The return periods of earthquakes in the Eastern United States were predicted using Type III statistics of extremes. Three sites were chosen for study. One, Anna, Ohio is a midwest location of moderate activity. The second, New Madrid, Missouri is a very active area. The third, Bloomington, Indiana is between the first two locations.

Type III statistics indicate that the most probable intensities for Anna, Bloomington, and New Madrid are, respectively, II^{+}, III^{-}, and III^{+}. Application of the method also predicts return periods for intensity VI for the same sites of 40, 250, and 16 years, respectively.

Historically Authentic Masonry Materials in the Renovation of Christ Church Cathedral. JOHN B. PATTON, Indiana Geological Survey, Bloomington, Indiana 47401.——The original part of the "little church on the Circle" in Indianapolis, Christ Church Cathedral, was built between 1857 and 1859. Renovation now in progress has required identification and matching of masonry materials for authentic restoration and preventive maintenance.

Bearing walls consist mainly of Laurel Limestone (middle Silurian), which was formerly quarried extensively in various southeastern Indiana counties. Quoins, buttresses, and some trim are from a thinly laminated zone in the middle part of the Jeffersonville Limestone (middle Devonian), probably from northwestern Jennings County. Steps and most trim, including belt course, lintels, sills, and surrounds for door and window embrasures, are Salem Limestone (middle Mississippian) from the famed "Indiana Limestone" district in the Bedford-Bloomington region. Careful work has thus far avoided the necessity of replacing any stone.

The masonry joints are being routed by hand to a minimum depth of nearly an inch where the old mortar is sound and to firm mortar elsewhere. Interior voids and the deep parts of routed joints are filled. After this first-stage mortar has set, the mortar is brought forward to less than an inch from the face and again given time to harden, after which final pointing is done with mortar that closely approximates the original in appearance. The binding agent is two-thirds lime and one-third natural-cement mortar (the original was entirely lime). The aggregate for both the original mortar and the present pointing is more coarse than modern masonry sands. Joints are raked shallowly and brushed, retaining the outlines of the individual stones by shadow and light.

Classifications of Springs in South-Central Indiana. RICHARD L. POWELL, Consulting Geologist, Bloomington, Indiana 47401 and STEPHEN D. MAEGERLEIN, Analytical Chemist, Naval Weapons Support Center, Crane, Indiana 47522.——Spring waters issuing from carbonate bedrock of Mississippian Age in south-central Indiana may be classified according to their chemical characteristics. The springs may be ranked by size according to their discharge. The spring orifices may be classified according to their physical characteristics. The subterranean water systems may be defined accordingly.

Spring discharges range from seeps to hundreds of cubic feet per second. Seventeen springs in Indiana are estimated to exceed one cfs minimum flow.

Spring waters are generally cool and clear with an increasing carbonate content during low flow stages, and are warmer and turbid with a decreasing carbonate content during flood flow stages. Mineral springs with a high sulfate content are fed by deep ground water flow systems, but some shallow cavern flow systems have a higher than expectable sulfate content that indicates some transmissivity of deeper groundwater.

Numerous examples of several types of subterranean water systems are present: bedrock interstices systems; systems within bedrock joints and fractures; gravity flow systems within integrated, solution widened joints and solution channels; integrated, partly inundated, gravity flow and shallow artesian systems through cavernous channels; deep artesian systems, probably within cavernous openings; and combinations of the above.

Eight springs larger than one cfs are gravity flow cave springs. Six large springs are partly inundated or combined artesian and gravity flow cavern systems. The three largest springs are associated with deep artesian systems.

Surface Morphology of Fly and Bottom Ash as Seen with the Scanning Electron Microscope

DONALD W. ASH, Department of Geography and Geology
Indiana State University, Terre Haute, Indiana 47809

THOMAS FERNALLD, Department of Geological Sciences
SUNY-Binghamton, Binghamton, New York 13901

Introduction

While studying the gound water flow system underlying a fly ash landfill site near Dunkirk, New York, it became apparent that because particle size and shape play an important role in the determination of porosity, permeability, and other ground water flow characteristics, the study should include a characterization of the physical appearance of both fly and bottom ash. In addition, the identification of these materials is essential in determining the amount of fly and bottom ash within the nearby stream and Lake Erie sediments. This initial morphological description was carried out with the use of the scanning electron microscope (SEM). This report describes our findings to date of cenospheres (hollow spheres), plerospheres (filled spheres), omphalospheres (bellybutton spheres; omphalos, from Greek for bellybutton), glass, scoriaceous material (full of vesicles or small bubbles), and crystalline overgrowths.

The fly ash consisted of two samples: 1) new fly ash collected in May 1976 from a dump truck which had just been filled from the electrostatic precipitator hopper at the Niagara Mohawk Power Company at Dunkirk, New York and, 2) old fly ash collected from the Fredonia Airpark, Fredonia, New York in late May of 1975. The airfield was constructed in 1966; thus, the airpark fly ash was nine years old at the time of collection. The bottom ash examined was all new bottom ash collected in May of 1976.

Results

Micrograph 1 shows typical fly ash morphology; it tends to form into many very smooth surfaced spheres (cenospheres) of different sizes. Also, note the scoriaceous (spongelike) material in the center of the micrograph. Although this material is more common in bottom ash, it is also found in abundance within the fly ash as well. Note that nearly all the vesicles and bubbles within the scoriaceous material are filled with small cenospheres (micrograph 2). Micrographs 1 and 2 are new fly ash samples. Even though the older fly ash has been in the environment nine years, its surface textures and morphology are little changed from that shown in micrographs 1 and 2. Perhaps the only notable difference is that apparently some of the cenospheres are missing or not as abundant in the vesicles of the scoriaceous material of the fly ash (micrograph 3).

Micrograph 4 (new ash) shows a closeup view of the center of micrograph 1. Note that the scoriaceous material is coated with cenospheres. And, the surfaces of these cenospheres are in turn coated with smaller adhering spheres. Higher magnification shows that these small adhering spheres have even smaller adhering spheres on their surfaces. However, the higher magnification does not allow reproducable micrographs to be made and thus they are not shown here.

It has been reported in the literature that crystalline overgrowths on new fly ash are quite common and apparently form gradually as the spheres cool after development (1). In examining several hundred samples of both old and new fly ash, no crystalline overgrowths were found. This apparent discrepancy may indicate that crystalline overgrowths are a function of coal source rather than being common to all fly ash.

According to Fisher et al (2), the occurrence of certain fly ash morphologies is indicative of the sulphur content of the coal burned. The most indicative of these morphologies is the occurrence of plerospheres in the ash content of high sulphur coal. Since the coal burned at Niagara Mohawk Power Company's Dunkirk plant is eastern high sulphur coal and plerospheres were found within the ash, this study supports their conclusions (micrograph 5). In addition, as another possible indicator of high sulphur coal this study has noted characteristic surface indentations on the surfaces of a large number of cenospheres (micrographs 6 and 7). These surface indentations have the appearance of a navel and thus we named spheres having this indentation omphalospheres from the Greek "omphalos" for bellybutton. A careful search of the literature has failed to yield a description of this feature. Since most of the literature we reviewed deals with low sulphur coal and we dealt

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Micrograph 1: *This micrograph shows typical fly ash morphology. There are many smooth shaped cenospheres of different sizes and the scoria mass in the center of the micrograph has its vesicles filled with cenospheres. The width of the field of view is 220 micrometers.*

Micrograph 2: *This micrograph shows a closeup view of a fly ash scoria block. It should be noted that the vesicles are completely filled with cenospheres. The width of the field of view is 22 micrometers.*

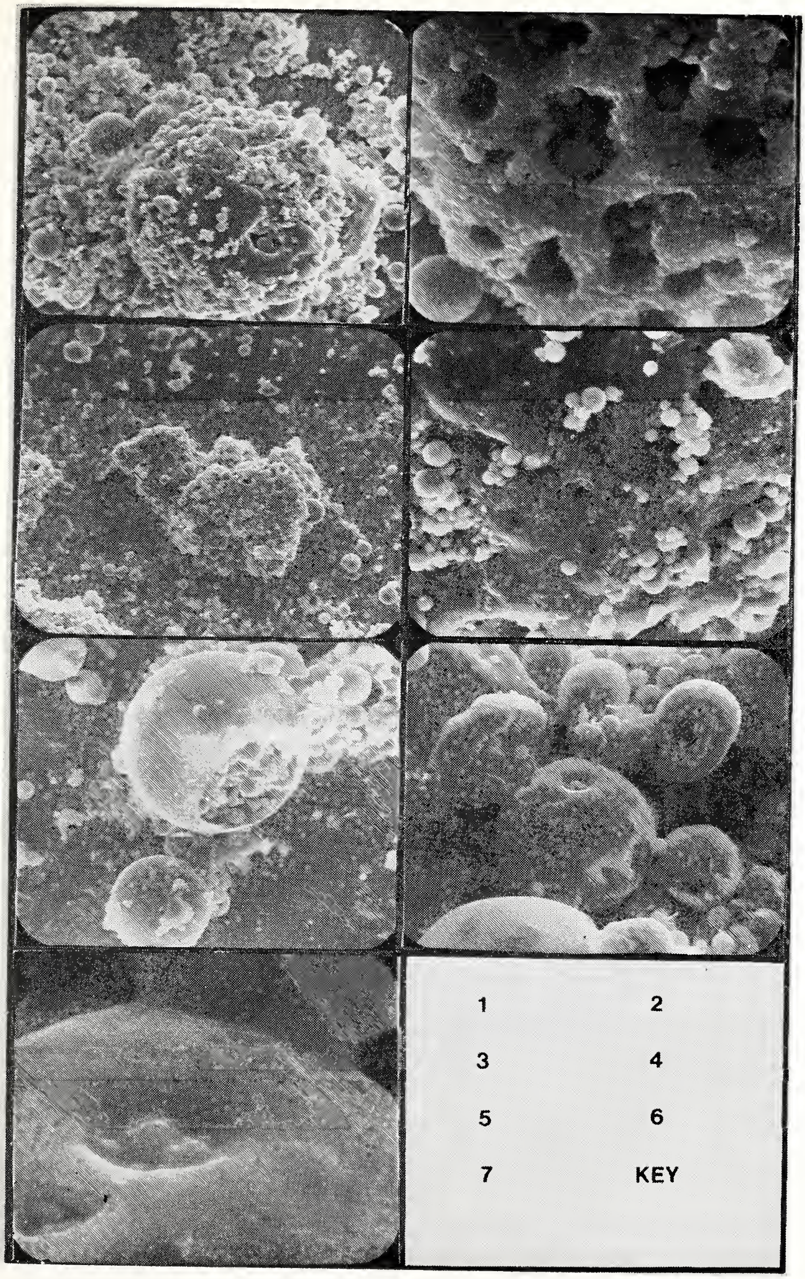
Micrograph 3: *This micrograph shows the morphology of some of the older fly ash. Note that there is little difference in the morphologies displayed among micrographs 1, 2, and 3. The width of the field of view is 220 micrometers.*

Micrograph 4: *This micrograph is a closeup view of the center of micrograph 1. Note that the scoriaceous material is coated with cenospheres and that the cenospheres have even smaller cenospheres attached to their surfaces. The width of the field of view is 55 micrometers.*

Micrograph 5: *Micrograph 5 shows a good example of a plerosphere. Note that the large sphere near the top center of the micrograph is filled with smaller cenospheres. If these smaller spheres are in turn broken open, they would be seen to also be filled with spheres. The width of the field of view is 110 micrometers.*

Micrograph 6: *This micrograph shows several cenospheres which have one or several indentations on their surfaces. We have named these omphalospheres and believe they are indicators of a high sulphur coal source. The width of the field of view is 55 micrometers.*

Micrograph 7: *This micrograph is a closeup view of the omphalosphere in the center of micrograph 6. It shows detail of the surface indentation. The width of the field of view is 11 micrometers.*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with coal having high sulphur content, we believe omphalospheres are either indicative of high sulphur coals or a certain coal source. The only article we reviewed dealing with low sulphur coal (2) has several micrographs showing what appear to be omphalospheres. It is difficult to be sure because the loss in quality from print to reproduction in the article obscures the detail. On this basis, it is felt that omphalospheres are indicators of a high sulphur coal source.

Bottom ash tends to be somewhat more coarse than fly ash approaching sand size and consists mainly of scoriaceous material (micrograph 8) in which the vesicles are nearly always empty (micrograph 9). As shown in micrograph 9, there are some spherical bodies associated with bottom ash. These spherical bodies tend to be 3 to 10 times larger than fly ash and are less regular in shape. As shown in micrographs 10 and 11, these bottom ash spheres come in two morphologies. The least common of the two types is the scoria pseudosphere (micrograph 10). It consists of scoriaceous material in the shape of a sphere. It is very easy to distinguish from true fly ash spheres. The second and more common type is shown in micrograph 11. At lower magnifications these spheres look very much like fly ash spheres. However, at higher magnifications all resemblance between the two ceases (micrograph 12). Compare micrograph 12 with micrographs 6 and 7. It can be easily seen that the surface texture of the fly ash spheres are much smoother. Thus, the spheres of bottom ash characteristically have rougher surfaces and larger sizes.

In addition to the previously described morphologies, there is common to old and new fly and bottom ash an amount of amorphous material. This glass material is shown in Micrograph 13. Also, in bottom ash, clinkers are found in some abundance (micrograph 14).

MICROGRAPH 8: *This micrograph show typical bottom ash morphology. Note that it is more coarse than fly ash and that the vesicles do not appear to be filled with cenospheres. The width of the field of view is 550 micrometers.*

MICROGRAPH 9: *This micrograph shows a closeup view of the surface of bottom ash scoriaceous material. Note that the vesicles are empty. The width of the field of view is 55 micrometers.*

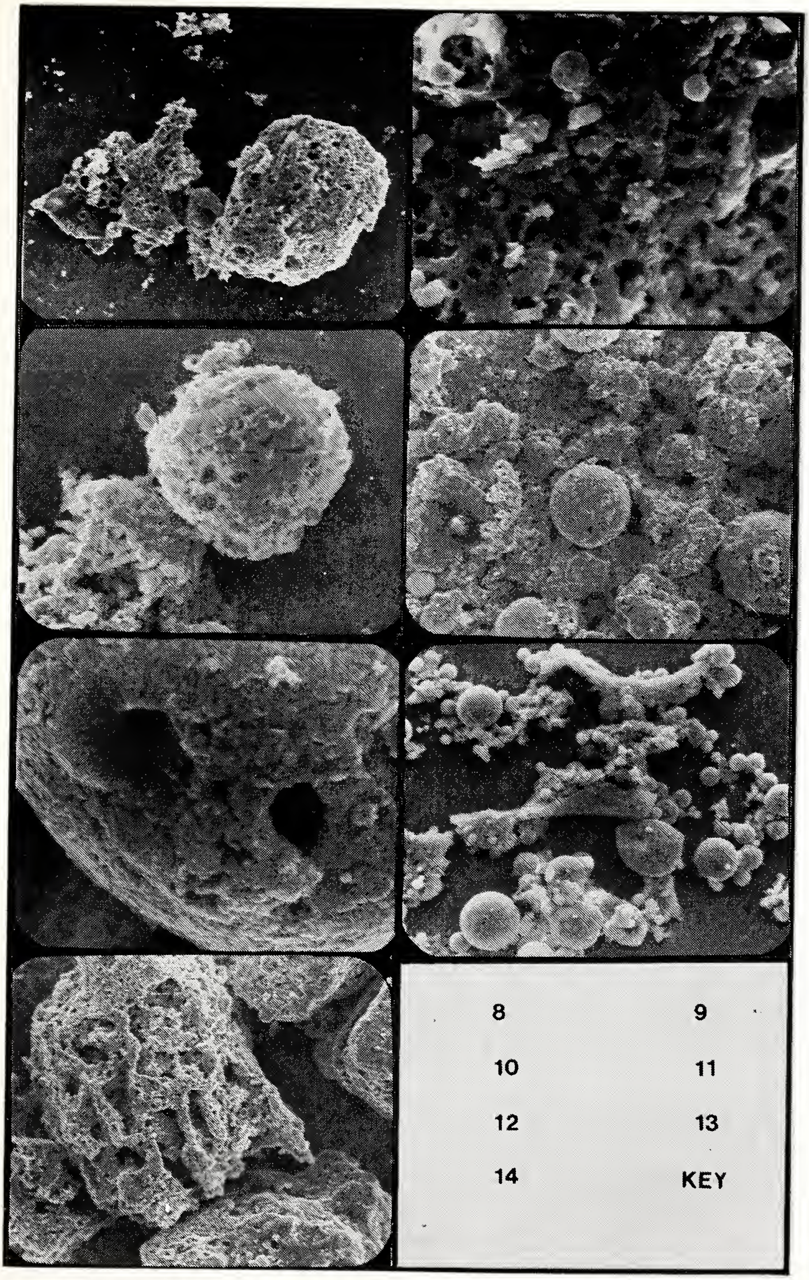
MICROGRAPH 10: *This micrograph shows a scoria pseudosphere from bottom ash. This is one type of sphere common to bottom ash. Comparing micrograph 10 with micrograph 6, one can see that it does not resemble fly ash. The width of the field of view is 110 micrometers.*

MICROGRAPH 11: *This micrograph shows the more common form of sphere common to bottom ash. Note that they are larger than most fly ash spheres. The width of the field of view is 550 micrometers.*

MICROGRAPH 12: *This micrograph shows a closeup view of the bottom ash sphere in the center of micrograph 11. Note that at this higher magnification the surface of the sphere is much rougher than that of fly ash (compare with micrographs 5 and 6). The width of the field of view is 55 micrometers.*

MICROGRAPH 13: *This micrograph shows an amount of glass material which is common to both fly and bottom ash. This sample is from fly ash as can be determined from the abundance of cenospheres within the micrograph. The width of the field of view is 22 micrometers.*

MICROGRAPH 14: *This micrograph shows a bottom ash clinker. These clinkers are not common in fly ash. The width of the field of view is 550 micrometers.*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Conclusions

Fly and bottom ash morphologies and surface textures as seen with the SEM are quite indicative and can be distinguished from each other. In addition, certain morphologies (plerospheres and omphalospheres) may indicate a high sulphur coal source. The lack of crystalline overgrowths on our samples may indicate that crystalline overgrowths are a function of coal source rather than being common to all fly ash.

The morphologies found are enough different from those of stream and lake sediments that the SEM will be a useful tool in examination of stream and lake sediments for fly and bottom ash pollution.

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Environmental Geology of Carroll County, Indiana

Roger F. Boneham
Department of Geology
Indiana University at Kokomo
Kokomo, Indiana 46901

and

Keith Burton
Maconaquah High School
RR 1, Bunker Hill, Indiana 46914

This report was compiled from information available in a recent soil survey of the county and from 705 water well logs in the files of the Water Resources Division, Indiana Department of Natural Resources.

The post-glacial drainage pattern in Carroll County is similar to the pre-glacial drainage. Soil cover is generally thick enough to present few construction problems from excavations reaching bedrock. Groundwater is of satisfactory quality except for hardness and, in some wells, high iron content. There are many areas which are suitable for housing developments. However, developers should heed the soil type carefully. Not all areas are suitable for septic systems. Carroll County has a number of sites which appear to be acceptable for sanitary landfills.

Purpose and Scope

The purpose of this report was to document the geologic factors in Carroll County which will have an impact on future development of the land. The information we used has been from published records or from the open files of the Water Resources Divison in Indianapolis. The most frequently used published records for this paper were Ulrich (4) and Wayne *et. al.* (6). The Water Resources Division of the Indiana Department of Conservation allowed us to copy information from the water well logs in their files. A similar study was done for adjacent Howard County earlier by the senior author (1).

Setting

Carroll County is located in the north-central portion of Indiana. The county seat is Delphi which is approximately sixty-five miles northwest of Indianapolis. The population of the county is approximately 18,200 (3) and there are approximately 374 square miles of land within the county.

The land is nearly level to gently rolling over much of the county. Stream valleys are seldom more than thirty feet deep. The major exceptions to this are the valleys of the Tippecanoe and Wabash Rivers in the northwestern part of the county. Local relief in their valleys is one hundred feet or more at a number of points.

Geology

The whole county was covered by the Wisconsin-age glaciers (5). Most of the material deposited by the melt-waters of these huge ice masses is still covering the bedrock of the area. This debris of sand, gravel, and clay has completely buried the old, pre-glacial drainage ways. In only a few places along the valley walls of the Tippecanoe and Wabash Rivers, have these large rivers succeeded in washing away the mantle of glacial material to expose the bedrock.

The post-glacial drainage system is not significantly different from the pre-glacial drainage. The flow is still to the south and west as it was before the coming of the Wisconsin ice sheet. The pre-glacial drainage can easily be traced on the bedrock surface map (Figure 1). This cover is not of a uniform thickness. There are a few areas where it is quite thin (Figure 2). The only present rock quarries are just west of Delphi where the limestone is within a few feet of the surface. There are numerous small gravel pits mainly in river valleys. These appear to be isolated pockets and our study has not located any significant new sources of gravel.

The underlying bedrock ranges in age from the Upper Devonian New Albany Shale to the Middle Silurian Niagaran Series composed of carbonate rocks (limestones and dolomites) and siltstones. Figure 3 is the geological map we have made from the water well logs and from

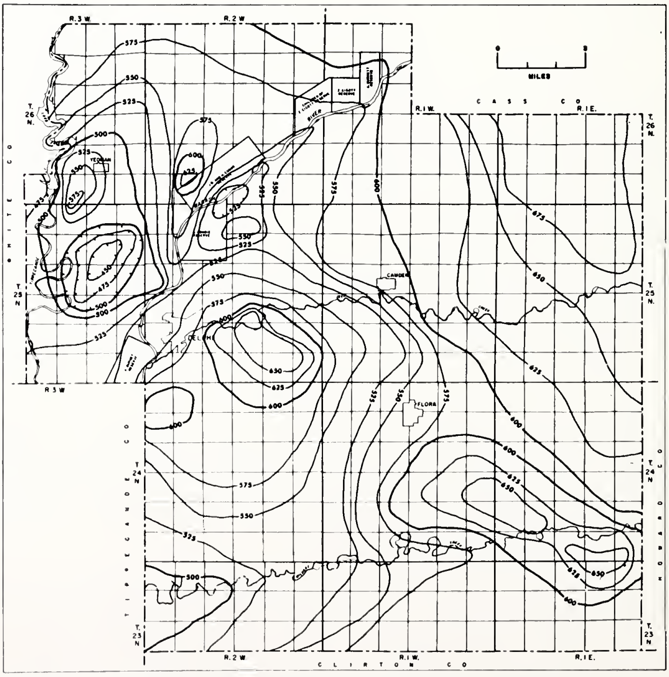


FIGURE 1. *Bedrock surface in Carroll County. The elevations are in feet above sea level.*

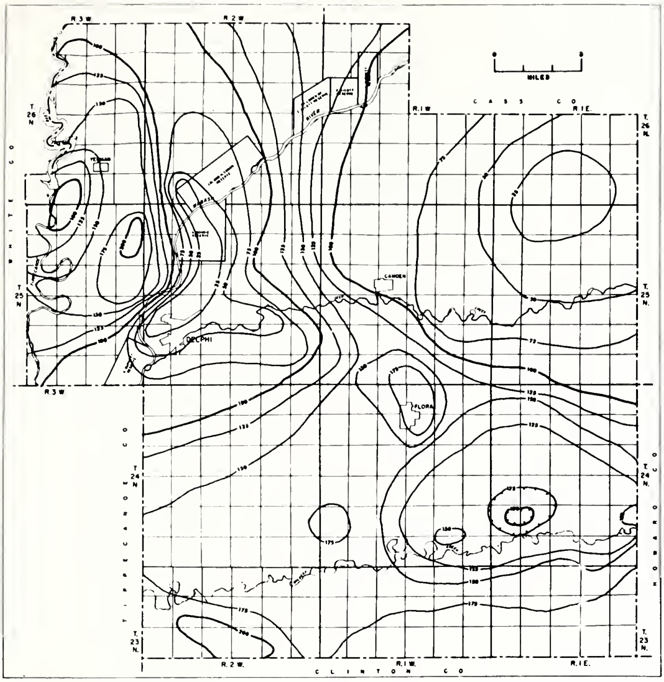


Figure 2. *Thickness, in feet, of glacial drift covering Carroll County.*

Wayne *et. al.* (6). Numerous wells have been drilled into the carbonate rocks with varying success. Some have produced water in excess of 100 gallons per minute. While others have flows of five or six gallons per minute. There seems to be no overall pattern to the groundwater flow in the limestones and dolomites. Undoubtedly, this is due to the characteristically tortuous nature of their joint patterns. There are no wells producing water from the New Albany Shale. This is a fissle, black shale which has limited permeability. Therefore, a water well must be drilled through the shale to the underlying carbonate rocks in order to obtain water. Generally the New Albany Shale is less than twenty feet thick in the county so the expense of drilling through it is not excessive. Many wells are drawing water from the sand and gravel layers located at irregular intervals within the mantle of glacial material overlying the bedrock. These wells have widely differing flow rates. Water quality generally is good. Table 1 illustrates hardness is a problem and iron is present in undesirable quantities in some wells.

We suggest that the most dependable water supply in the county is the larger rivers which flow through the area. A city seeking to increase its water delivery system or a company considering an expansion of its operations could obtain large amounts of water from the Wabash or Tippecanoe Rivers. Even Wildcat Creek or Deer Creek would supply more than enough water for any reasonable use.

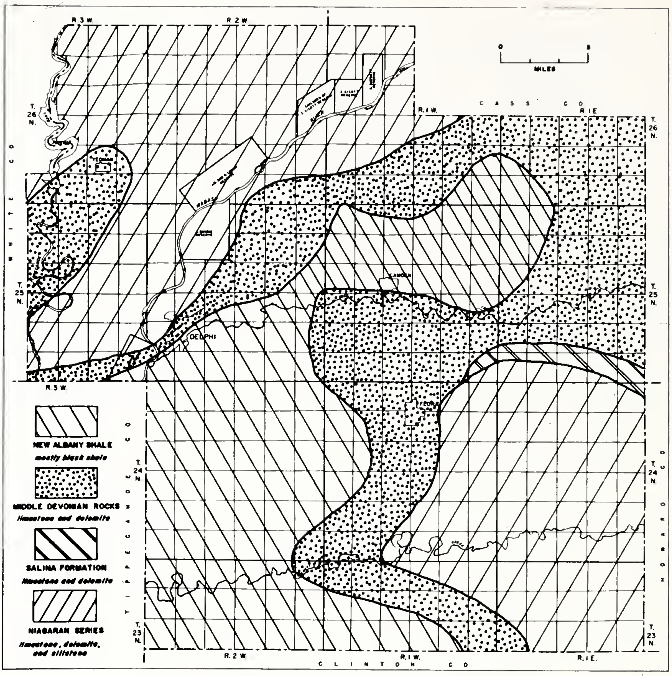

R. 3 W.
R. 2 W.
R. 1 W.
R. 1 E.
MILES
CASS CO
CLINTON CO
WHITE CO
TIPPECANOE CO
HOWARD CO
T. 26 N.
T. 25 N.
T. 24 N.
T. 23 N.
DELPHI
CAMDEN
FLORA
NEW ALBANY SHALE
mostly black shale
MIDDLE DEVONIAN ROCKS
limestone and dolomite
SALINA FORMATION
limestone and dolomite
NIAGARAN SERIES
limestone, dolomite, and siltstone

FIGURE 3. *Geological map of Carroll County.*

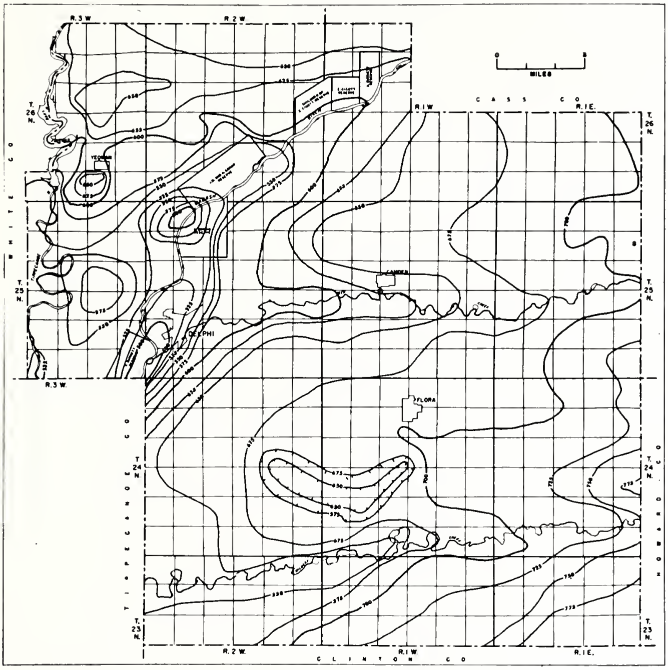
The flow of the groundwater is to the west and south (Figure 4) as is the surface water flow. An exception to this is an area southwest of Flora. There is a pocket toward which groundwater flows from all directions. We cannot account for this behavior since it does not

TABLE 1. *Raw water quality in Carroll County.*[1]

	Camden (2 wells)	Delphi (7 springs)	Delphi (2 wells)	Flora (1 well)
pH	7.2–7.5	7.6	7.2	7.4
Color s.u.	<5	0	0–<5	5
Turbidity s.u.	0.4–10	0	0.1–0.2	5
Hardness as $CaCO_3$	330–347	350	414–447	346
Calcium as Ca	83	95	89–108	94
Magnesium as Mg	31–34	28	43–47	27
Sodium as Na	11–15	4	10–13	4
Potassium as K	2	2	2–5	1
Iron as Fe	1.2–2.4	0	<0.03–0.6	1.8
Manganese as Mn	<0.05	0	0.01	0.1
Alkalinity as $CaCO_3$	342–348	278	313–342	290
Chlorides as Cl	4–7	5	10–14	8
Sulfates as SO_4	6	50	70–100	57
Nitrates as N	0–0.1	3.0	0.8–3.6	0.1
Fluorides as F	0.4	0	0–0.4	0.1

[1] Data from Indiana State Board of Health (2). All columns in milligrams per liter (mg/l) except pH, color, and turbidity.

appear to be a buried sinkhole. This type of map is particularly useful if any wells should become contaminated in the future. It will provide a reference as to the general direction from which the pollutants most likely came.


R.3 W
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MILES
C A S S C O
R I W
R.I E.
T. 26 N.
T. 25 N.
T. 24 N.
T. 23 N.
W H I T E C O
T I P P E C A N O E C O
H O W A R D C O
C L I N T O N C O
YEOMAN
DELPHI
CAMDEN
FLORA
R.3 W.
R. 2 W.
R.I W.
R.I E.
650
625
600
575
550
675
700
725
750
775

FIGURE 4. *Elevation, in feet above sea level, of groundwater pressure surface in Carroll County.*

We classified the soils in Carroll County into three main groups as to their suitability for septic system drainage fields (Figure 5). The good soils have no restrictions on the ability to absorb effluents from septic tanks. These soils are Fox (0-12% slope), Longlois, Meta, Miami (0-12% slope), Monitor, Ockley, Ross, and Russell (0-12% slopes). The fair soils have limitations on their capacity to absorb large amounts of water. Developers planning subdivisions on these soil types should consider a central waste treatment facility rather than individual septic systems. These fair soils are Abington, Brookston, Cope, Crosby, Fincastle, Homer, Kokomo, Sleeth, Sloan, Washtenaw, and Westland. Areas with soils classified as poor should not be used for tract housing. These soils have been placed in this category for a number of reasons. Soils having excessive slopes are: Fox (12%+ slope), Hennepin, Miami (12%+ slope), Rodman, and Russell (12%+ slope). Building structures on these soils will be difficult and septic systems are unlikely to be effective on such grades. The effluent is dispersed downslope too rapidly for the soil bacteria to destroy the wastes. Soils which are excessively

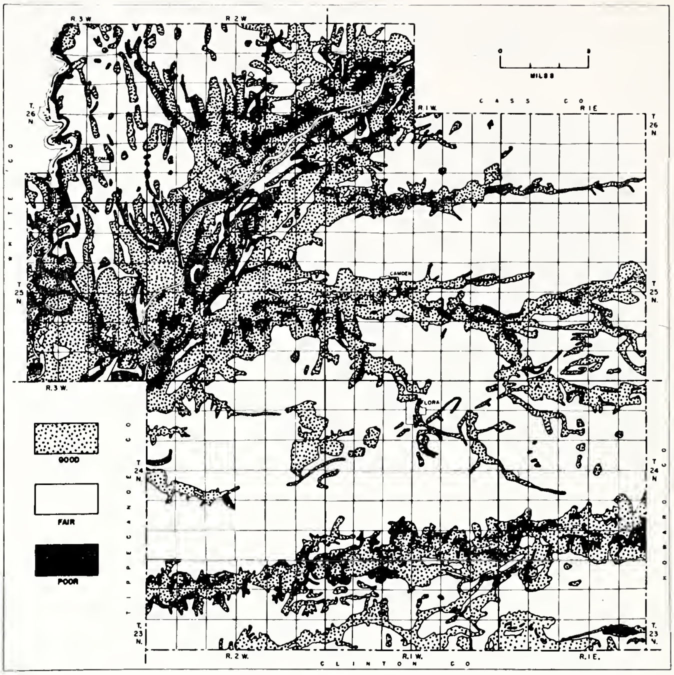
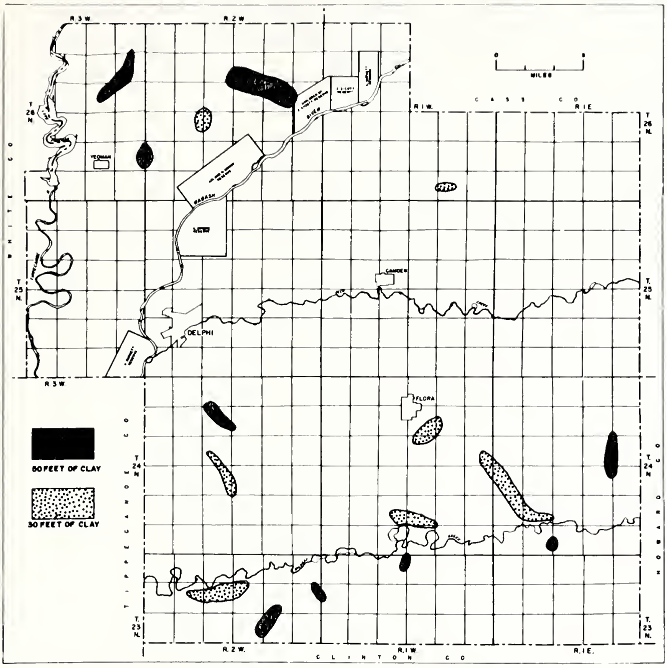


FIGURE 5. *Suitability of soils in Carroll County for septic tank filter fields.*

drained are Nineveh and Oaktown. These contain large amounts of sand and some gravel. Here again, the soil bacteria cannot detoxify the wastes of septic tanks due to their high rate of movement. The Carlisle, Edwards, Linwood, and Lyles are soils which have developed in depressional areas. Drainage is toward rather than away from these tracts and often there is a very high content of organic matter in the soil. Drainage is not the only problem for these soils. They also provide an unstable base for building foundations due to their high muck content. The Eel and Genesee soils have reasonably good drainage. But they are soils which develop on flood plains of rivers and are subjected to occasional flooding. We do not recommend that houses be built on flood plains. The Farmington, Millsdale, and Milton soils are very thin and developed in areas where bedrock is close to the surface. The excavations for building foundations would likely uncover bedrock. This would make housing development more costly; particularly if trenches had to be blasted in the bedrock for utility lines. Septic systems should not be used in these soils due to the likelihood of contaminating the groundwater by leakage into the neighboring bedrock.

There are a number of potential sites for sanitary landfills within the county. The areas shown in Figure 6 are the most likely sites due to their clay content. It is assumed that the trench method would be used in any landfill operation in Carroll County. The waste should


R 3 W
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YEOMAN
WABASH
RIVER
CAMDEN
DELPHI
FLORA
50 FEET OF CLAY
30 FEET OF CLAY
TIPPECANOE CO
HOWARD CO
R. 3 W.
R. 2 W.
R. 1 W.
R. 1 E.
CLINTON CO

FIGURE 6. *Areas in Carroll County which are potential sites for sanitary landfills.*

be sealed as well as possible from any leakages into the groundwater. The best sites are those with fifty feet of clay measured from the surface downwards. Less desirable sites, but still acceptable, are those with a depth of thirty feet of clay. The Indiana State Board of Health recommends a minimum bottom seal of five feet of clay. However, ten feet of clay would be better since this standard may be revised upward at sometime in the future.

These are suggested localities based upon the clay content of the area. It would be necessary to do much more field work at a specific site before making a final decision on a sanitary landfill site. The depth of the watertable must be accurately measured and the direction of groundwater flow should be determined. Also, the contour of the land is critical since surface drainage should be carefully protected from contamination.

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A Study of the Geologic Section at Bloomington, Indiana, Using Rayleigh Wave Displacement Amplitude Ratios

Ralph W. Knapp
Judson Mead
Robert F. Blakely
Department of Geology
Indiana University
Bloomington, Indiana 47401

Abstract

The elliptic particle trajectories of Rayleigh waves in the frequency of range 0.5 to 2.0 hertz produced by coal mine explosions and recorded at Bloomington, Indiana, were studied to determine whether the particle motion conformed to the theoretical prediction for Rayleigh waves propagating on an elastic, horizontally layered half space and could, therefore, be used to determine the elastic parameters of layers within the sedimentary section beneath the receiver.

Surface waves from two hundred mine blasts were digitized at a sampling rate of 10 points per second and recorded on magnetic tape. The results of analysis show that the phase difference of the horizontal and vertical components is statistically scattered about the value of $\pi/2$, the theoretically predicted value, and that values of the displacement amplitude ratio, defined as the ratio of the magnitude of the horizontal component to the magnitude of the vertical component, can be fitted to values calculated from an elastic parameter model of the geologic section at Bloomington.

It is concluded that structural irregularities have had little noticeable effect on the results and that the observation of displacement amplitude ratios may be a useful means of determining the gross structure of sedimentary basins.

Introduction

Rayleigh waves are seismic waves which propagate on the surface of the earth with a particle displacement contained by the vertical-radial plane such that the particle trajectory is elliptical and retrograde.

The eccentricity (displacement ratio) of the ellipse of motion is a function of the medium in which the Rayleigh wave is travelling. Layering introduces a frequency dependence. The displacement ratio value is measured as the ratio of the radical to the vertical spectral amplitude of the Rayleigh wave.

$$E(nf) = |A_r(nf)|/|A_v(nf)| \tag{1}$$

The spectral dispersion of the displacement ratio depends almost solely on the seismic section beneath the recording station and is independent of the travel path or source. The dispersion is a function of density, layer thickness, and compressional (P) wave velocity; and is particularly sensitive to shear (S) wave velocity. The particular attractions of the use of displacement ratios to the study of the structure of geologic layering are that an interpretation is derived from a single point of observation and that the study provides knowledge of S wave velocity, the least accurately determinable body wave.

The use of displacement ratios to study the structure of geologic layering was first done by Lee in the 1930's (6,7); hindered by the burden of the calculation, he was limited to a two layer interpretation. The method has recently been applied to the study of the lower crust-upper mantle of the continental United States (2,10,11) and to the determination of the shear velocity structure at Apollo sites 12, 14, and 15 on the moon (9).

This study is an application to the interpretation of the sedimentary structure of the west flank of the Cincinnatti Arch under Bloomington, Indiana.

Assumptions

Spectral dispersion for a theoretical model, calculated using the Thompson-Haskell matrix method (4), requires that the model be an infinite half space with perfectly horizontal and planar layers. The west flank of the Cincinnatti Arch has a gentle slope of about 0.5 percent; the interfaces are not planar; and the layers wedge out on the surface of the earth. To apply a modelling method to the inversion of displacement ratio data, the discrepancies between the geologic section and the model requirements must be negligible.

Experiments with the propagation of Rayleigh waves on wedges (5) have demonstrated that the effect of a 5 percent wedge is negligible; however, the presence of surface irregularities is likely to cause complications by the regeneration of seismic energy by the incidence of the original seismic signal on a surface or interface topographic feature. The effect of interfering noise on amplitude and phase modulation has been found to be quite dramatic (2). If the noise is random with respect to the signal, the effect can be diminished statistically, but if the noise correlates with the signal, such as regeneration, the effect may result in irrecoverably altered data.

Geologic Setting

Because the spectral dispersion of displacement ratios depends only on the strata beneath the receiver, the section immediately beneath Bloomington is of interest. For this study both the geologic and the P velocity control were provided by studies of the Luther Brown test well in Lawrence County. This well is stratigraphically down strike from Bloomington; it is one of only a few wells drilled to the Precambrian in Indiana; and it is the only well with a continuous velocity log from the New Albany Shale to the basement (1,3). The depth to strata surfaces is slightly greater at Bloomington than at the test well; this is reflected in the models which were developed.

Of the parameters other than P velocity and layer thickness needed to calculate the dispersion properties of a model, the average Poisson's ratio is estimated to be 0.33 for sedimentary basins and density was assigned the value 2.5. The modelling process refined the initial estimates somewhat. Shear velocity for a Poisson's ratio of 0.33 is half the P velocity.

Procedure

Seismic signals are continually recorded digitally onto magnetic tape at the seismic station at Bloomington. The sampling rate is 10 points per second with a resolution of 12 bits for all three components. The signal is amplified and converted from long period Sprengnether seismometers.

The signals analyzed in this study mostly originated from surface coal mines located 45 to 140 kilometers west and southwest of Bloomington (figure 1). The signals are dispersed in the frequency range 0.4

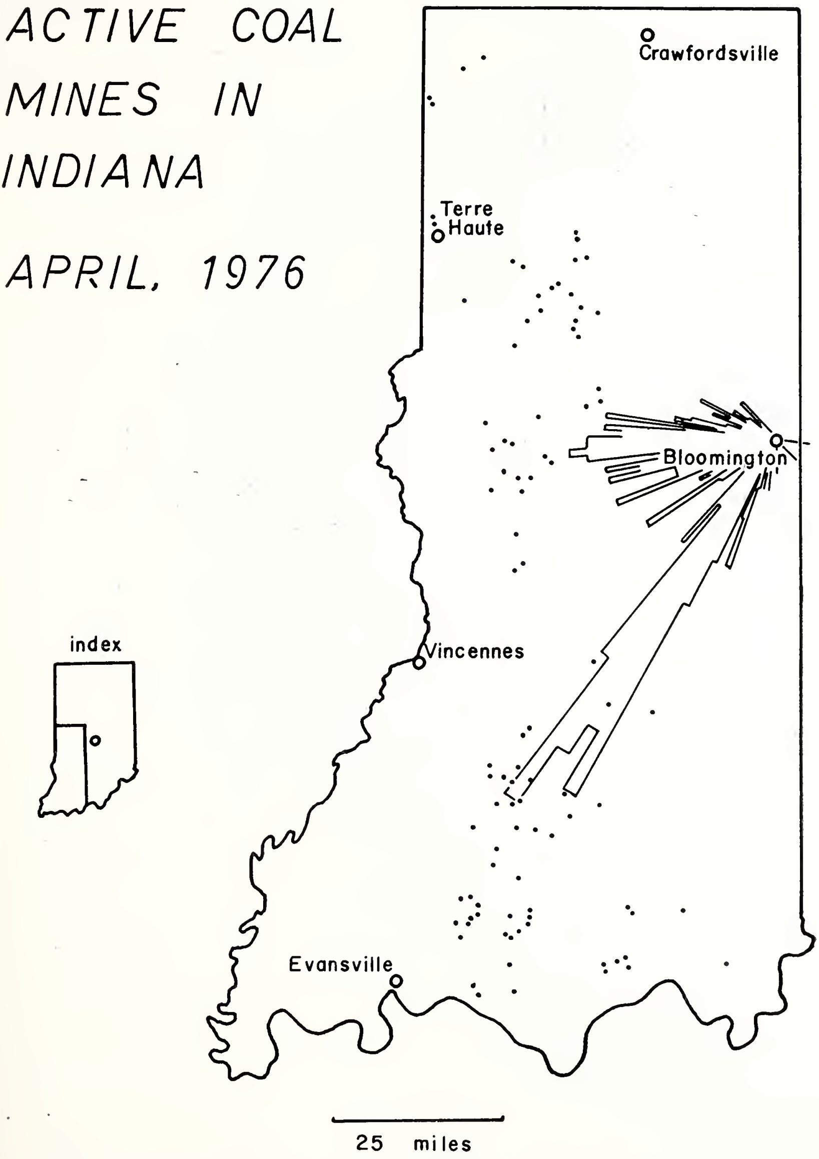
ACTIVE COAL MINES IN INDIANA
APRIL, 1976
Crawfordsville
Terre Haute
Bloomington
Vincennes
Evansville
index
25 miles

FIGURE 1. *Distribution of coal mine activity in Indiana as of April 1976. The rose diagram is the azimuthal distribution of the signals studied, 1 inch = 5 events per 2 degree wedge.*

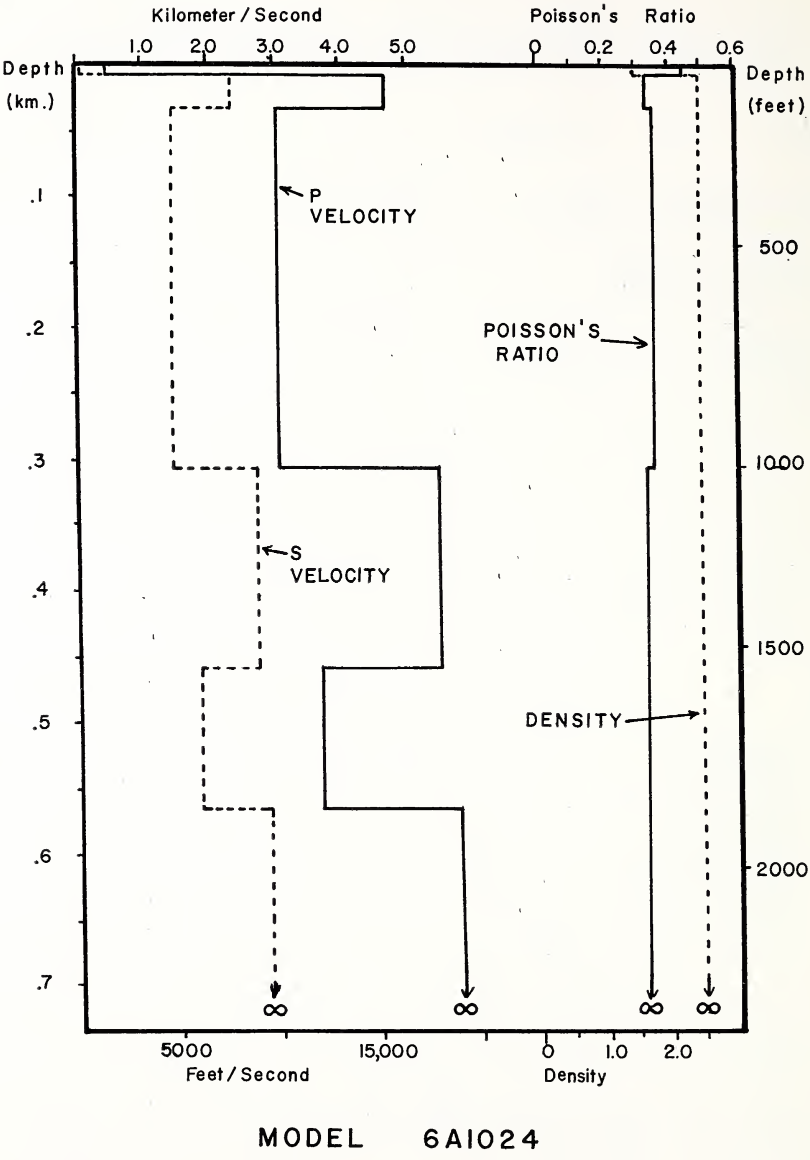

FIGURE 2. *Model 6A1024, a model of the elastic structure of the upper 1.5 kilometers of the geologic section beneath Bloomington, Indiana, which provides a reasonable fit to the data.*

to 2.0 hertz. It is in this frequency range that surface waves are most greatly influenced by the sedimentary section.

Because of the pronounced effect of noise modulation on the signal it was necessary to look at a large number of events so that random noise could be statistically removed. Two hundred events were used. To process the data in a reasonable length of time expedient methods were developed. The desired events are transcribed from a continually recorded tape to a condensed archive tape. Each event is filtered and inspected for acceptance; the source direction is established by correlating the phase shift filtered vertical component with the horizontal component; and the displacement ratio and the phase difference are calculated as functions of frequency for each event. Coalescing all events, the average values of displacement ratio, phase difference, and the vector length are determined. The data is discriminated according to the value of the mean vector length, a measure of data coherence (8). Once the data is evaluated a geologically reasonable model is determined by a trial-and-error process which compares the data with mathematical models.

Results

A good tentative model for the geologic section is model 6A1024 (figure 2), which fits the data as shown in figure 3. The larger deviations in the data (e.g., at 0.95 hz., 1.05 hz., 1.2 hz.) are due to the interference of correlational noise and cannot be removed statistically. The poorness of the fit above 1.6 hertz has two possible explanations: either the model is not a correct representation, or the data is erroneous at the higher frequencies. Perturbation curves and the trends of the models developed suggests that the first explanation may not be correct.

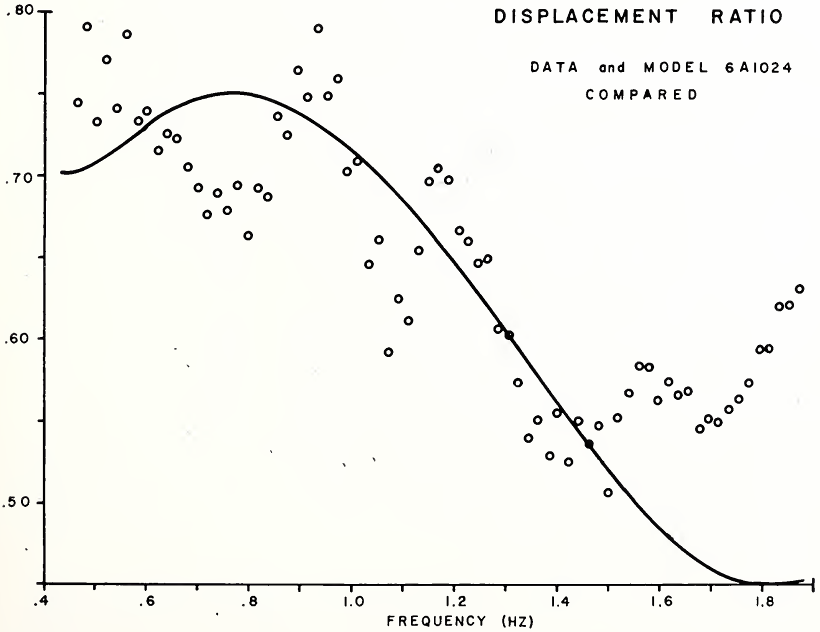

FIGURE 3. *The comparison of the model and the data. The data points are the result of the statistical reduction of over 5000 observations.*

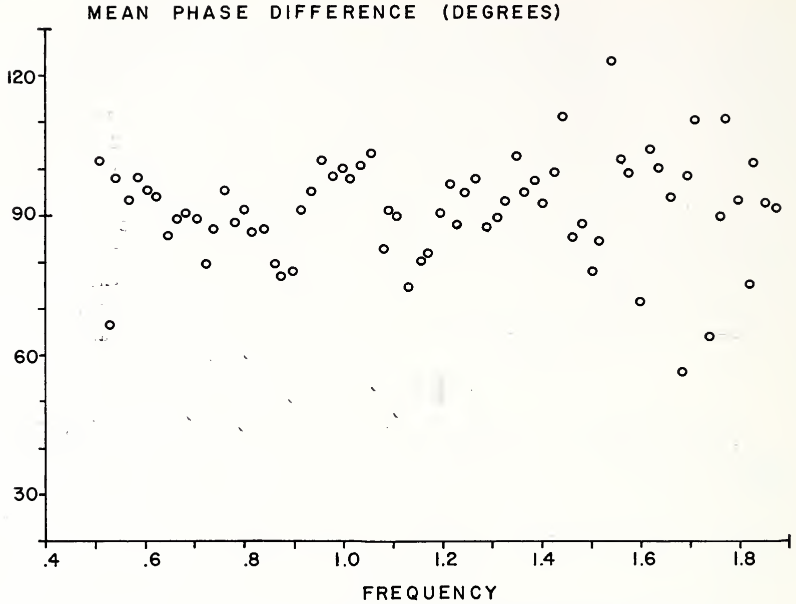

Figure 4. *Mean phase difference of the vertical and radial components.*

The scatter at the higher frequencies of the mean phase difference (figure 4) suggests that the Rayleigh wave is not well behaved theoretically above 1.6 hertz, and the low values at the higher frequencies of the mean vector length (figure 5) indicate that the signal is not very coherent above 1.6 hertz. This supports the second explanation.

The randomness and lack of theoretical behavior may be due to the departure of the seismic station geometry from the requirements of the theoretical calculation. The required presence of twenty feet of overburden may be a partial compensation of the effect of the seismic station pier rather than indicating the presence of 20 feet of alluvium in Bloomington.

Conclusions

The use of displacement ratios is an interesting and novel means of studying the seismic properties of the geologic section in a horizontally layered region. With a systematic method of analysis the derived information is broader than the information derived solely from P wave studies because S velocity, Poisson's ratio, and density information is derived as well as P velocity and layer depths. The method is cheaper than reflection methods, and, in areas with low velocity layers, is more accurate than refraction methods.

The method would be most advantageously used in conjunction with a surface wave velocity analysis technique because the observations are independent and results would have a greater resolution. A tripartite station arrangement with stations 2-5 kilometers apart is suggested. It appears that the observations in this study exceeded the upper frequency limit of the Bloomington seismic station and that the seismometers should be set at bedrock level to study high frequency Rayleigh waves.

It is felt that the effect of correlational noise while quite noticeable in the data had a rather minimal effect on the interpretation of the data.

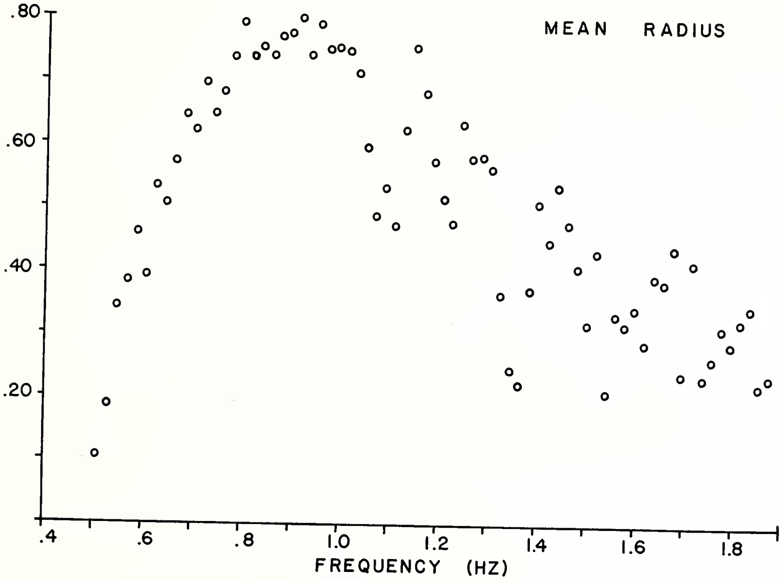

FIGURE 5. *Mean vector length (radius) of the phase vector.*

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A New Crinoid Fauna from the Harrodsburg Limestone (Mississippian) of Southern Indiana

JAMES R. WELCH and N. GARY LANE
Department of Geology
Indiana University, Bloomington, Indiana 47401

Abstract

A recently discovered crinoid fauna from the lower three meters of the Harrodsburg Limestone (Osagian; Mississippian) along Judah Branch, southern Monroe County, Indiana, provides new evidence for the age relations of the Bono and Canton crinoid faunas in Indiana. Fossils from Bono, Lawrence County, and Canton, Washington County, were collected in the 19th century and these localities and their stratigraphic positions are not now known. The new site has yielded 15 species of crinoids, nine of which have been reported from Canton and three from Bono. Other species found include one known from the Ramp Creek Formation below the Harrodsburg and one also found in the Salem Limestone above. This new locality thus supports the hypothesis of Lane (1972) that the Canton fauna is of early Harrodsburg age and that the Bono fauna is slightly younger, but also of Harrodsburg age. The Judah Branch fauna is almost equally divided between inadunate crinoids (8 species) and camerates (6 species) with one flexible crinoid. The fauna is thus intermediate in terms of community evolution between the Canton fossils, dominated by inadunates, and the Bono crinoids, in which camerates are predominant.

Introduction

During the latter part of the 19th century a series of Mississippian age crinoid faunas were described from Indiana that were typically attributed to what was called a "Keokuk" age. This meant that these Indiana rocks and fossils were judged to be of the same age as the Keokuk Limestone, the uppermost formation of the Osagian series of the Mississippian, which crops out along the west side of the Illinois Basin. This crude correlation included rocks that were limestones as well as siltstones and shales and there was little attempt to relate these various Indiana faunas to each other. One such attempt resulted in placement of these crinoid faunas in an upside-down sequence (1).

Two of these important crinoid faunas were described from Canton and Bono, Washington and Lawrence counties, Indiana. These localities have been lost for many years and attempts to rediscover the levels from which crinoids were collected have so far been unsuccessful. This paper reports for the first time the definite occurrence of elements of both of these older faunas in the lower part of the Harrodsburg Limestone, thus providing firm evidence that it was at or near this stratigraphic position from which both of the older faunas were obtained.

Although much of the Harrodsburg Limestone is crinoidal limestone, occurrences of articulated, well-preserved crinoids are rare. This is unfortunate because the Harrodsburg marks a major environmental and depositional change from deltaic sedimentation (Borden Group) to a shallow-water carbonate bank (Salem Ls.), and important changes in the composition of crinoid faunas occur within this interval (2).

Stratigraphy

The Harrodsburg Limestone is the middle unit of the Sanders Group (4) and grades into the overlying Salem Limestone and underlying Ramp Creek Formation, which together make up the Sanders Group. The new crinoid fauna (Table 1) was found 2.5 m above the Ramp Creek Fm. (fig. 1), which is commonly called part of the lower Harrodsburg in older literature. This fauna, along with fossil crinoids from Canton and Bono, constitute the youngest crinoids known from the Osagian Series of the Mississippian. The Osage-Meramec boundary occurs someplace in the middle of the Harrodsburg Limestone. Crinoids from the Ramp Creek on Indian Creek, Montgomery Co., Indiana, and from the lower Harrodsburg record youngest occurrences of Osagian crinoids known. Several genera and families of crinoids become extinct after final appearances in the Ramp Creek or lower Harrodsburg. One suborder, the dicyclic camerate crinoids Diplobathrida, is also last represented in these faunas. The upper Harrodsburg Limestone contains a

TABLE 1. *Fauna from the Harrodsburg Limestone at Judah Branch Creek roadcut, Monroe County, Indiana.*

Crinoids
Abrotocrinus orestes (Worthen)
Abrotocrinus sp.
Barycrinus cf. B. stellifer Miller
Cribanocrinus benedicti (Miller)
Cyathocrinites gurleyi (Miller)
Cyathocrinites harrodi (Wachsmuth & Springer)
Cyathocrinites nodosus (Wachsmuth & Sprinter)
Decadocrinus bellus (Miller & Gurley)
Dichocrinus simplex (Shumard)
Dichocrinus ulrichi Miller & Gurley
Dizygocrinus cantonensis (Wachsmuth & Springer)
Dizygocrinus facetus (Miller & Gurley)
Forbesiocrinus cf. F. washingtonensis Miller & Gurley
Histocrinus sp.
Hylodecrinus asper Kirk
Hypselocrinus hoveyi (Worthen)
Platycrinites bonoensis (White)
Other Echinoderms
Cryptoblastus sp.
Onychaster sp.
Postibulla legrandensis (Miller & Gurley)
Other Invertebrates
Cladochonus beecheri (Grabau)
Cleiothyridina hirsuta (Hall)
Echinoconchus alternatus (Norwood & Pratten)
Fenestrate bryozoans
Fistulipora compressa Rominger
Fistulipora spergenensis Rominger
Ovatia ovatus (Hall)
Phillipsiid sp.
Platyceras (Orthonychia) sp.
Spirifer tenuicostatus Hall
Spirifer washingtonensis Weller
Sulcoretepora sp.
Zaphrentoides sp.

crinoid fauna that is Meramecian in aspect and is closely similar to that of the overlying Salem Limestone.

The Osagian-Meramecian boundary is one of the most important boundaries for change in fossil crinoids in the entire Paleozoic sequence. These two series names are commonly grouped together into the Valmeyeran Series, or Middle Mississippian, but because of the paleontological significance of this boundary Osagian and Meramecian are preferred here to Valmeyeran.

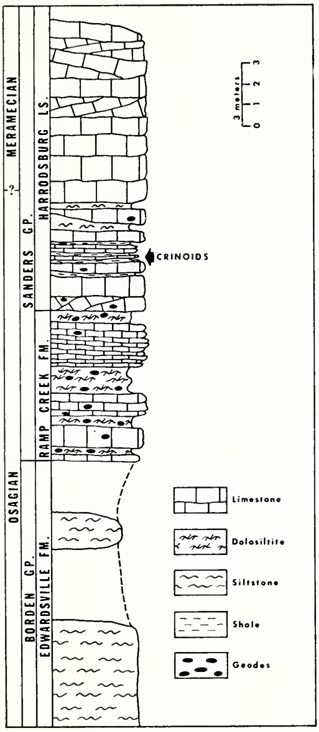

FIGURE 1. *Measured section on Bypass SR 37 at Judah Branch Creek showing the stratigraphic location of the Harrodsburg crinoid fauna (at arrow). Section starts in the bed of Judah Branch Creek and extends south up the hill to the top of the roadcut. Contact between the Harrodsburg and overlying Salem Ls. is not exposed. Exact position of the Osagian-Meramecian boundary is uncertain.*

Locality Description

This fauna comes from a roadcut on the SR 37 bypass where it ascends the hill on the south side of Judah Branch Creek, in the NE¼, SE¼ sec. 32, T. 7 N., R. 1 W.: Monroe County, Indiana, Indiana University Locality No. 13395. The locality was originally discovered by Alan S. Horowitz (Indiana University) and Donald B. Macurda (University of Michigan) in the summer of 1974; subsequent quarrying at the site produced much additional material.

Crinoids were collected from two different "pockets" at the same horizon on opposite sides of the highway. On the east side of the road, the fossils occur on the upper surface of a discontinuous limestone bed overlain by 6 cm of shale. The edrioasteroid, *Postibulla legrandensis*

(Miller and Gurley, 1894), was found in this "pocket" only where specimens were attached to the inside of brachial valves of *Echinoconchus alternatus* that were lying upside-down on the limestone surface. The blastoid, ?*Cryptoblastus*, was also only found in this "pocket".

Crinoids from the west side of the road were in the lowermost 0.5 cm of a silty shale bed overlying a bioclastic limestone bed; all within an area of 1.5 sq. m. As many of the crowns still have long segments of stem attached and occur at one thin level, they were probably killed and buried by a single influx of silt and clay that formed the shale bed.

Curiously, the blastoid, *Pentremites*, was not present within either "pocket", although common both above and below this horizon. The echinoid, *Melonechinus*, was also collected at this outcrop but not from either "pocket". Many other invertebrates were associated with the crinoids; an incomplete listing is given in Table 1.

Significance of the Crinoid Fauna

This new crinoid fauna shows closest resemblance, at the species level, to the fauna that was collected near Canton, Indiana. The following species found at the new locality have been reported in the literature, or are present in the Springer collection of the U.S. National Museum, from Canton: *Barycrinus stellifer*, *Cyathocrinites gurleyi*, *C. harrodi*, *Hypselocrinus hoveyi*, *Decadocrinus bellus*, *Forbesiocrinus washingtonensis*, *Dizygocrinus cantonensis*, *D. facetus* and *Platycrinites bonoensis*. This represents 9 of the 15 crinoid species that could be identified to the species level found at the new site. Of these nine species two, *C. harrodi* and *C. nodosus*, are also found at the old Indian Creek locality and one, *P. bonoensis*, is also found at Bono, Indiana, where it was the most abundant crinoid. Two species, *D. ulrichi* and *C. benedicti*, have been found at Bono but not reported elsewhere from the eastern side of the Illinois Basin. One species, *D. simplex*, is known from the overlying Salem Limestone but has not been reported previously from the Harrodsburg or older rocks. Finally, *Abrotocrinus orestes* was described from the Keokuk Limestone but has not been reported previously from Indiana.

These species relationships suggest that the crinoids from the new site are similar in faunal composition to the Canton fauna. However, the three most abundant crinoids at Canton, *Actinocrinites*, *Scytalocrinus*, and *Synbathocrinus*, are not present in the new fauna. The Judah Branch fauna is seemingly intermediate in relationship to the Indian Creek fauna from the Ramp Creek and to the Bono fauna.

The differences and similarities among these several closely related crinoid faunas may be ascribed to slight differences in ages of the rocks that contain the fossils, or to differing environmental conditions that controlled the presence or absence of crinoid species. A strong case for overall environmental control on gross taxonomic composition of crinoids in communities of this age has been made by Lane (3), who showed that in passing from deltaic to carbonate bank conditions there was a progressive diminution in proportion of inadunate crinoids and an enhancement of camerate crinoids. The new Judah Branch fauna furnishes additional evidence for such sequential changes in these communities. Details of age relations among these crinoid communities are poorly known and await further study. Two outstanding questions concern whether or not the Ramp Creek Formation is equivalent to the upper part of the Borden Group or to the lower Harrodsburg in those areas where the former unit is absent or very thin, and whether the Harrodsburg may not be time-transgressive as carbonate sedimentation gradually encroached over the Borden delta. If such time relations were to be demonstrated then the Indian Creek crinoids of the Ramp Creek, situated north of other faunas, may be equivalent in age to the Canton or Bono faunas farther south. The differences among these faunas would then be due to differing environmental controls across central and southern Indiana during early Mississippian time.

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Astogenetic Variability in a Frond of *Polypora laevinodata* (Hall) (Bryozoa)

James F. Stratton, Eastern Illinois University, Charleston, Illinois 61920
Alan S. Horowitz, Indiana University, Bloomington, Indiana 47401

Abstract

Evaluation of seven characters does not reveal any systematic differences between the oldest and the youngest parts of a large frond of *Polypora laevinodata* (Hall) from the Middle Devonian Speed Member of the North Vernon Formation. Consequently, studies of fragments of fronds will not necessarily produce biased zoarial measurements or provide the basis for excessive taxonomic splitting. Future work should test the hypothesis of rhythmic banding in large fronds of fenestrate bryozoans.

Fragments of fenestrate bryozoans are much more common in the fossil record than complete fronds and fragments commonly are the subject of taxonomic descriptions in the paleontological literature. Quantitative studies of the variability within individual fenestrate fronds are almost lacking. Consequently the availability of a nearly complete frond of *Polypora laevinodata* (Hall) provided the stimulus for a study in astogenetic variability.

Cumings (1, p. 70-74) discussed the earliest development of colonies of *Polypora* M'Coy, but discussions of the later stages of colonial growth in *Polypora* or other fenestellid genera do not appear generally in the literature. Cumings (1, p. 66) noted that in *Fenestella* Lonsdale little or no change in characters could be observed in early to later stages of colonial growth.

Elias (2) prepared a color scheme for illustrating the changes from early to late stages of growth in a single character (fenestrule length) in large fronds of *Fenestella.* The colors generally displayed a banded pattern related to stages of growth in a colony as discussed by Elias. However, no tests were made to determine the significance of the differences nor were any special edge features described to indicate the criteria for late versus early growth stages. Elias (2, p. 375) suggested that some of the concentric banding in the pattern of fenestrule length was seasonal. We have not examined our data from the standpoint of rhythmic banding because it requires a different experimental approach than reported herein. However, future studies should be designed to test this hypothesis in other fenestrate bryozoan fronds.

An exceptional specimen of *P. laevinodata* (Hall) (IU15106-200) from the Speed Member of the North Vernon Limestone exhibited a nearly complete frond displaying lateral edge features and a distal growth margin and lacked only the earliest basal portion of the frond. The specimen, which is 12 cm high and 10 cm wide, was divided into seven 15 mm intervals perpendicular to growth. The proximal level represents, most probably, a part of the colony just above the basal structure as inferred from the width and general geometry of the flabellate frond. The distalmost level contains edge features and also the growing edge, which confirms that this is the position of the youngest part of the colony.

Seven external characters (number of apertures in 5 mm, branch width, number of branches in 10 mm, dissepiment width, fenestrule length, fenestrule width, number of fenestrules in 10 mm) used for differentiating species of *Polypora* within the Speed Member and Jeffersonville Limestone (4) were used in the astogenetic study. No internal sections were made because of some alteration and surface silicification; however, chamber shape was observed on partially weathered areas of the frond and was consistently box-like (quadrangular) wherever observed.

Although the data sets of most measured characters of *Polypora* from the Speed Member and the type suites of the polyporans from the Jeffersonville Limestone were not normally distributed (4), the data sets for each measured character from the different levels of the specimen chosen for the astogeny study approached normality more closely than other sets of measurements from the population. The reason for this is probably due to the small number of measurements involved in the analysis, which decreases the power of the test (i.e. the test results are affected by the small sample size). The different measured intervals on the specimen used in the astogeny study were tested with nonparametric and parametric methods.

A Mann-Whitney U test, a nonparametric test using rank order of the original data, was used to test for association between levels of the specimen. Because of the large number of ranking ties between various levels on each measured character the results of this test suggested no difference between levels, proximally to distally on the frond. All characters tested nonsignificant at a probability level of 0.05. Because the failure of this test to show differences between levels might be caused by the large number of ties between data sets, a parametric test was also performed by applying the central limit theorem to the means of each measured character from each of the intervals. Sokal and Rohlf (3, p. 130) suggest in a discussion of the distribution and variance of means that means of samples drawn from any distribution will approach the normal distribution; this is known as the central limit theorem. A Kolmogorov-Smirnov test (3, p. 571) on the means from composite data of fenestrule width of the astogenetic specimen *P. laevinodata* revealed that the means were normally distributed; the null hypothesis was accepted a probability level of 0.05.

A one-way analysis of variance, using the Student-Newman-Keuls (SNK) test, repeated t-tests, and Tukey's test, tested the associations between all characters for all levels in all combinations of levels; the rejection level for the null hypothesis was set at $p=0.05$. These tests of analysis of variance revealed little difference between the proximal and distal intervals of the frond. Dissepiment width changed significantly but this is not considered the best diagnostic character in discriminating taxa and it did not change systematically within the frond, e.g. smaller to larger as the frond matured or vice-versa. In most cases involving comparisons of the same character between levels, the repeated t-test was more powerful in showing lack of association. Even this test revealed lack of association between intervals in only a few cases, i.e.

discounting dissepiment width, only 25 out of 126 comparisons were significantly different. Complete tables of results can be found in Stratton (4).

The variation observed in the astogenetic study was similar to that observed within other populations of *P. laevinodata* to which this specimen was taxonomically assigned. This suggests that the differentiation of taxa within the polyporans based on the measured characters from zoarial fragments is valid because of the demonstrated minor variation within characters as the colony grows.

At the distal extremities of the astogenetically studied specimen and in other specimens showing a lateral margin, the overall characters change within 5 to 10 mm of the edge of the frond, excluding the growing tip. These changes are due to the secretion of additional calcite at the lateral distal edge, which is presumably involved in structural support of the frond. At the lateral extremities of the colony, excluding the growing tip, the fenestrule length and fenestrule width decrease rapidly and a correspondingly significant increase in branch width and dissepiment width is present; ultimately the dissepiments fuse into a massive structural support along the edge that extends from near the base to an area near the growing tip to the proximal part of the colony. This structural support appears to migrate toward the growing tip as the colony increases the size. When this marginal thickening spreads across the growing edge, it signals the end of growth for the colony.

We conclude that fragments of fronds will not necessarily yield biased measures of characters provided the fragments are sufficiently large (not less than 1 cm square) to permit complete meshwork measurements.

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Preliminary report on a Late Pleistocene death-trap fauna from Monroe County, Indiana

STEVEN ALAN VOLZ, Department of Geology, Indiana University,
Bloomington, Indiana 47401

Abstract

Fragmented remains of numerous Late Pleistocene mammals have been collected from a gryke in the Salem Limestone of Monroe County, Indiana. This gryke, which was exposed during construction on State Highway 37, has yielded remains of *Platygonus vetus, Smilodon fatalis, Canis dirus, Canis lupus, Canis* cf. *latrans, Ursus americanus* and *Neotoma* sp.

Of the remains collected the most abundant are from *Platygonus vetus* and from carnivores, particularly *Canis dirus.* This evidence suggests that the accumulation resulted from entrapment of susceptible animals in a natural cavity from which escape was not possible, although some remains may have been imported by activities of the wood rat. The high degree of fragmentation of the preserved material is interpreted as the result of slow burial and periodic disturbance by rodents and newly entrapped animals.

Acknowledgments

This writer wishes to thank William Turnbull of the Chicago Museum of Natural History for his generosity in allowing access to the vertebrate collections and willingness in answering questions. Also, thanks are given to Phillip Gingerich of the University of Michigan Museum of Paleontology for allowing similar access to the vertebrate paleontology collections of that institution and for his help with several questions. Further, the writer acknowledges the Department of Geology at Indiana University for financial support of the museum trips and for defraying costs of the radiocarbon dating that was done by Geochron Laboratories. Finally, this writer acknowledges and thanks Donald Hattin of the Department of Geology at Indiana University for his review and editing of this manuscript.

Introduction

In April of 1974 the writer participated in a sedimentation and stratigraphy field trip led by William Pullen and the late Ned Smith of Purdue University. The party discovered a few scattered teeth and skeletal remains of some Late Pleistocene animals in a road cut situated south of Bloomington, Indiana. The remains were preserved in clayey deposits of a large gryke which occurs within a hill underlain by Salem Limestone. The fissure had been transected by the then recently completed State Highway 37. The site lies about nine tenths of a mile south of Zikes Road on the east side of the highway (see Plate 1).

This paper is the result of two subsequent collecting expeditions in the winters of 1974-1975 and 1975-1976 during which a portion of this deposit was removed for study.

Description of Deposit

The fossiliferous deposit lies within one of numerous grykes which occur along this stretch of highway. Before construction of the road, the grykes were completely filled by detritus consisting primarily of clay. These fissures are now being eroded. They may extend several meters laterally into the hillside and range in width from a few centimeters to a few meters.

The cavity from which the studied material came is about 1.5 meters wide and extends back 1.7 meters into the hillside from the edge of the road cut. Original dimensions of the fossiliferous gryke cannot be estimated; part of its length was destroyed by road building and the full depth can be determined only by further excavation. The top of the fossiliferous clayey deposit lies about 3.0 meters beneath the adjacent upland surface. Approximately 0.7 meters of fossiliferous clay has been removed from the gryke.

The sides of the gryke are nearly vertical and consist of well-weathered surfaces which have solution pits and secondary cave-type calcareous deposits. These sides extend to the upland surface with little overhang or beveling.

The fossiliferous deposit is more or less chaotic with only the clay fill having any semblance of stratigraphic order. Clay nearest to the upland surface is comprised of red to purple *terra rosa*. The *terra rosa* is underlain by brown clay, which is replaced laterally by *terra rosa* directly adjacent to the limestone walls. Beyond this no stratification is apparent.

The clay contains considerable numbers of much-fragmented mammal bones and teeth. No other macroscopic organic remains have been identified. The skeletal remains are jumbled haphazardly and usually are so fragmented as to be unidentifiable. Most often, the bone fractures have sharp edges although a few specimens appear to show wear by abrasion. Several specimens have been crushed. The best-preserved material consists of teeth most of which have been separated from the respective jaws. No complete bones more than 4 or 5 centimeters in length have been recovered. The extent of disarray of the deposit can be summarized best by the description of one block of collected material. This block, which was about the size of a man's fist, contained the posterior left portion of a dire-wolf palate, the hoof of a peccary and a large, unidentified, fragmented incisor. The block also contained countless splintered and unidentifiable bone fragments.

The most dense occurrence of these skeletal remains is in the brown clay although bones occur also in the lower part of the *terra rosa* mantle and in the *terra rosa* that lies against the limestone walls. Skeletal material occurs in abundance to the deepest level excavated and considerable amounts probably remain.

In addition to the mammal remains, the clay deposit contains a large number of scattered angular limestone fragments. These range in size from pebbles to boulders. These blocks were derived almost exclusively from the St. Louis Limestone which lies above the Salem

Limestone. The St. Louis no longer crops out in the immediate vicinity of the gryke; however, in the road cuts directly across the highway, a thin layer of St. Louis is recognizable at the top of the section.

In addition to the primary detrital fill, a considerable amount of secondary calcite occurs in the deposit. Usually the calcite nucleated around limestone or fossil fragments. Consequently, large masses of limestone fragments, fossil fragments and clay have been cemented together into irregular masses of material.

Recovery and Preparation of the Fossil Material

The fossiliferous clay was removed in bulk with a shovel, although especially well-preserved specimens were removed carefully by hand whenever possible. Good specimens were recovered from the secondary calcite masses and from clay that was free of calcite cement. Generally, better specimens were recovered from the calcite masses.

Owing to the frailty of the material, preparation of the vertebrate material was difficult and time consuming. Generally, a needle probe was used to pick away the calcite and clay. Some specimens disintegrated during this process, although many were saved by progressive application of coats of alvar during picking, and by immediate gluing of specimens broken during the cleaning process. Some specimens were sufficiently durable to be worked free without special treatment. These were later coated with shellac.

Despite a considerable amount of primary fragmentation, parts of the same specimen usually were located in close proximity, and many teeth or jaw fragments were reassembled from parts that unquestionably had been separated before final burial.

In addition to the picking and cleaning, some of the sediment was sifted. Several rodent incisors were recovered in this way.

Recovered Fauna

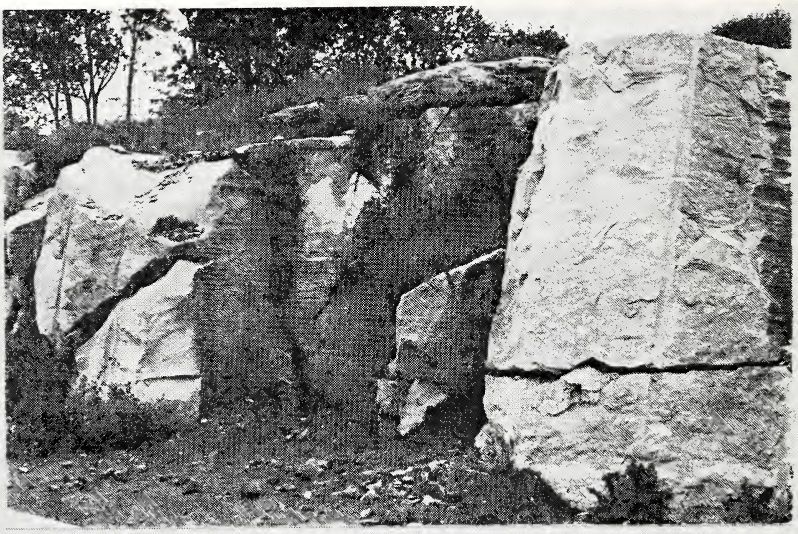
The following list includes species that are represented by fossils from the clay-filled gryke.

Platygonus vetus
Smilodon fatalis
Canis dirus
Canis lupus
Canis cf. *latrans*
Ursus americanus
Neotoma sp.

The assignment of specific names to these specimens and other points germane to them are discussed below.

Platygonus vetus

The most abundant material collected from the site consists of juvenile and mature teeth of the extinct genus *Platygonus*, a Late Pleistocene peccary (see Plate 1). Of particular note is the fact that many of these specimens are unusually large, larger than any *Platy-*



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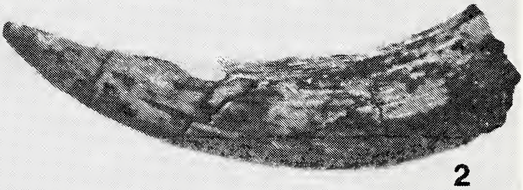

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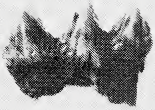

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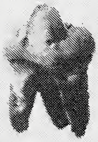

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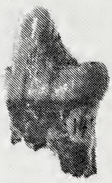

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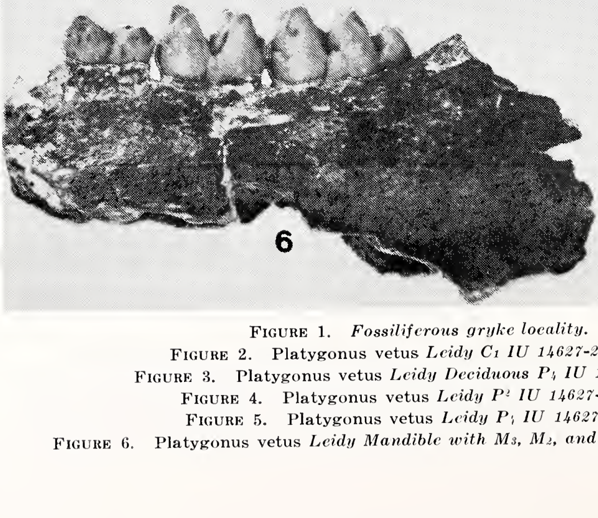

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FIGURE 1. *Fossiliferous gryke locality.*

FIGURE 2. Platygonus vetus *Leidy* C_1 *IU 14627-24* × *2/3*

FIGURE 3. Platygonus vetus *Leidy Deciduous* P_4 *IU 14627-40* × *1*

FIGURE 4. Platygonus vetus *Leidy* P^2 *IU 14627-11* × *1*

FIGURE 5. Platygonus vetus *Leidy* P_4 *IU 14627-8* × *1*

FIGURE 6. Platygonus vetus *Leidy Mandible with* M_3, M_2, *and* M_1 *IU 14627-1* × *2/3*

gonus material reported previously. In addition to numerous teeth, proximal, medial and distal phalanxes have been identified. (Indiana University 14627-45, 14627-46, 14627-47, 14627-48).

Presently, two or three species of *Platygonus* are recognized from the Late Pleistocene of North America. In order to understand the assignment of this material to *Platygonus vetus,* a brief review of these Late Pleistocene species is pertinent (for a more comprehensive review see Slaughter (20)).

In 1848, Dr. John L. LeConte described *Platygonus compressus,* a moderate-sized, Late Pleistocene peccary from near Galena, Illinois (11). Later, several Late Pleistocene species were assigned to this genus by various authors. Most of these subsequent species were based on material which differed from *P. compressus* in minor characters of the skull and/or in the size of the skull or dentition. With the discovery of a cave in St. Louis that contained numerous remains from *Platygonus compressus* (G. G. Simpson (18)), it became apparent that a single population of *P. compressus* could be composed of a wide range of individuals that varied both in size and in relative proportions of dentition and skull. The Simpson paper extended the size range upward for the dentition and skull of *Platygonus compressus,* while at the same time showing that several earlier-named species of *Platygonus* should be considered synonyms of *P. compressus.*

The size range for *P. compressus* was extended still further by Slaughter (20), following study of a population from Laubach Cave, Texas. Slaughter showed that the size range in this population overlaps that of the St. Louis specimens and in some cases that of the Kansas specimens. Taken together, he showed the three populations formed a continuous series of size range. Based on his specimens Slaughter also reassigned one other *Platygonus* species (*P. alemanii*) to *P. compressus.*

Both Slaughter and Simpson recognized that a second main species of *Platygonus* existed in the Late Pleistocene, *Platygonus cumberlandensis,* which was first found in Cumberland Cave, Pennsylvania (Gidley (4)). *P. cumberlandensis* cannot be differentiated from *P. compressus* by tooth measurements (the first species falls within the upper size range now recognized for the latter). Rather, *P. cumberlandensis* is recognized by extreme development of the zygoma, which is about one and one-third times the size of the vertical diameter of the orbit in females and two or more times the diameter of the orbit in males. *P. compressus* shows not much more than normal development of the zygoma.

A third Late Pleistocene species, *Platygonus vetus,* is also tentatively recognized. This species was proposed by Leidy (12) for fragments of an upper and a lower jaw from Pennsylvania. Today, this species remains separate because of its somewhat larger size than the other two Late Pleistocene peccaries and also because a skull has not been found with which to examine the zygoma and other characteristics. A single specimen from Cumberland Cave (a portion of the palate from a young individual) has teeth of about the same size and proportion as in *P. vetus*. Gidley (12) originally referred this specimen to *Platygonus vetus*. Later, Gidley and Gazin (5) considered that it might simply be a size variant of the other Cumberland Cave material but retained the original assignment, tentatively.

This brings up the possible synonomy of *P. cumberlandensis* and *P. vetus*. If *P. vetus* also showed an extreme development of the zygoma (i.e. if a skull with large dentition could be found with this zygoma), then *P. cumberlandensis* would be incorporated into *P. vetus*. If, however, this *P. vetus* skull showed no unusual development of the zygoma, then (assuming no other characters were found different enough to cause specific separation) *P. vetus* would become a synonym of *P. compressus*, and simply extend the size range of the latter species still further. Until a skull is found the relationship of *P. vetus* to the other two species will remain uncertain.

In the material I studied many *Platygonus* teeth are comparable in size to or even larger than the material reported for *P. vetus*. A few specimens, however, are in the upper size range of *P. compressus* (i.e. they are roughly the same size as *P. cumberlandensis*). Because no skull has been found, my assignment of the Monroe County material is made solely on the basis of tooth size. Consequently, this material is referred to the largest species known, *P. vetus*. This is not the first large Late Pleistocene peccary to be discovered in Indiana. Hay (8) reported an M^3 from Lawrence County which is comparable in size to material from my study site and which he referred to *P. vetus*.

Assignment of my specimens to *P. vetus* is done with the reservation that any one of five possible conditions could be true.

1. *P. cumberlandensis* is the same as *P. vetus*.

   If this is true, and it is supported by the fact that several of the specimens reported here are comparable in size to *P. cumberlandensis*, then *P. vetus* would be the appropriate name for these specimens.

2. *P. vetus* is the same as *P. compressus*.

   In this case, the upper limit of size range of *P. compressus* would be extended considerably and all *P. vetus* material would be referred to the species *P. compressus*.

3. *P. vetus* is a distinct species.
4. Two species are represented at the Monroe County site, *P. vetus* and either *P. compressus* or *P. cumberlandensis*.
5. Specific differentiation between the Late Pleistocene peccaries of the genus *Platygonus* should not be made on the basis of zygoma development.

   The trend defined by discovery of new populations of Late Pleistocene *Platygonus* has been toward simplification of the number of recognized species. This trend is owing primarily to the fact that individual populations demonstrate that these peccaries were highly variable not only in size but also in characters of dentition and skull. (Even Gidley (4) admitted that a wide variation of zygomatic development occurred in his Cumberland Cave material.) Consequently, the ultimate end product of this trend would be to classify all present species herein discussed as subspecies of *Platygonus compressus.*

Smilodon fatalis

Remains of saber-toothed cats are rare in the Midwest, this being the first report of material from Indiana. Included in this material are a right and a left P^4 (Indiana University 14627-51 and 14627-50) plus a right and left P^3 (Indiana Unuiversity 14627-54 and 14627-55) (see Plate 2).

Several Late Pleistocene species of the genus *Smilodon* have been proposed based on characters of skull and dentition. Merriam and Stock (14) showed that several of these characters could vary widely within a single population, based upon a large sample from the La Brea site. Consequently, later authors have reassigned several species which had been classified originally on characters that the La Brea material suggests are of subspecific rank.

Slaughter (19) recognized three well-defined species of *Smilodon* in North America, based upon dental indices constructed from lower dentition plus some supporting skull data. These three species are *Smilodon fatalis* (=*S. troglodytes, S. conardi, S. nebraskensis, S. trinitiensis*), *S. floridanus* (=*S. californicus*), and *S. gracilis.* Recent discoveries in Florida (Webb (24)) have tended to confirm Slaughter's view. Unfortunately, the Indiana material does not contain any part of the lower dentition that could be compared with Slaughter's results. Consequently, this material was assigned to *Smilodon fatalis* by other criteria.

First, measurements of the Indiana *Smilodon* teeth are consistently smaller than any of the material reported from La Brea and assigned originally to *S. californicus* by Merriam and Stock (14). These authors stated that ". . . it is questionable whether there are any upper fourth premolars of sabre-tooth in the large collection from California asphalt deposits which approach closely the size or at least the anterior-posterior diameter of the type of *S. fatalis.*"

Second, both Indiana P^4's show evidence that they had well developed protocones. On both specimens in the place where the protocone would normally be developed there is a conspicuous hole through the enamel. Both holes show that enamel at the marginal edges is well worn as if by use by the animal during mastication. Because a dominant proportion of *Smilodon* P^4's from La Brea contain no protocone and because the overall size of their P^4's is uniformly larger than many *S. fatalis* specimens, *S. floridanus* (=*S. Californicus*) can be effectively eliminated from consideration.

Based on the material from my study site, *Smilodon gracilis* cannot be separated easily from *S. fatalis.* The Indana material falls approximately at the upper end of the size range for *S. gracilis.* The main criterion that can be used to separate *S. gracilis* from my material is the greater age of *S. gracilis.* Hibbard (9) considered the deposit which yielded the original specimen of *S. gracilis* to be Yarmouthian in age. *S. gracilis* has not been reported from the Late Pleistocene which, as will be seen in a later section, is the age assignment of the Monroe County material based on the rest of the faunal association.

From the above I conclude that *S. gracilis* is not the best assignment for the species represented here. By elimination this leaves *S. fatalis* as the most likely species to which the Monroe County specimens should be assigned.

Canis dirus

The type specimen of *Canis dirus* Leidy was obtained originally from Pleistocene beds on the Ohio River near Evansville, Indiana. Within the Monroe County deposit, the second most abundant material obtained consists of teeth from this same great wolf (see Plate 2). The material matches so closely the La Brea dire wolf specimens in the Chicago Museum of Natural History that I have no doubt the Indiana material belongs to this species.

Canis lupus

Canis lupus Linné is represented in this deposit by a single, somewhat worn P^4 (Indiana University 14627-65) (see Plate 2). Its dimensions fall well within the range of modern subspecies of the grey wolf as presented by Goldman (7). It is not surprising to find *Canis lupus* preserved in fossil deposits because it was an indigenous species in Indiana at the time the first European settlers arrived.

Canis cf. latrans

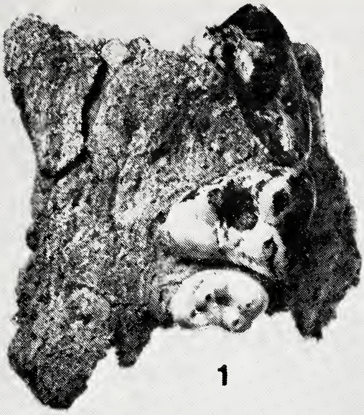
A third species of *Canis* is represented in this material by approximately the anterior one third of a right M^1 (Indiana University 14627-66). Its size and shape compares favorably with *Canis latrans* Say. The coyote is presently an indigenous species in Indiana.

Ursus americanus

The collection contains several teeth referable to the modern species of black bear, *Ursus americanus* Pallas. (See Plate 2.) These teeth corresponded closely in proportion and morphological characteristics with those in the collection of recent black bear skulls in the University of Michigan Museum of Paleontology. However, the Indiana fossils are somewhat larger, about the size of grizzly bear (*Ursus horribilis*) specimens in the same collection. This is to be expected. Presently, *Ursus americanus* shows considerable size differentiation over its geographic range and in most fossil reports, according to Kurten (10), *U. americanus* is described as being larger than the living animals. Black bear, like *Canis lupus*, became extinct in Indiana with the arrival of white settlers.

Neotoma sp.

The rodent material from Monroe County includes several incisors and one right M^1 (Indiana University 14627-49). The right M^1 can be



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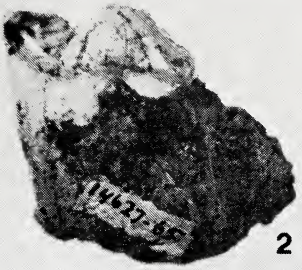

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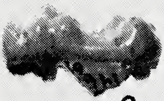

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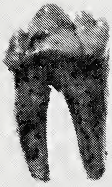

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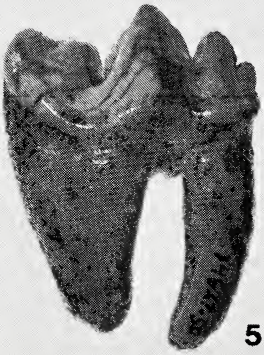

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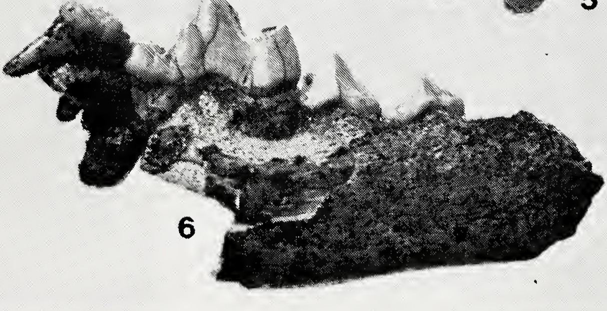

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FIGURE 1. Canis dirus *Leidy Maxilla with* P^4, M^1, *and* M^2 *IU 14627-88* × *2/3*
FIGURE 2. Canis lupus *Linne* P^4 *IU 14627-65* × *1*
FIGURE 3. Ursus americanus *Pallas* M_1 *IU 14627-64* × *1*
FIGURE 4. Smilodon fatalis *(Leidy)* P^3 *IU 14627-54* × *1*
FIGURE 5. Smilodon fatalis *(Leidy)* P^4 *IU 14627-50* × *1*
FIGURE 6. Canis dirus *Leidy Mandible with* P_3, P_4, M_1 *and* M_2 *IU 14627-69* × *2/3*

assigned to the wood rat, *Neotoma* Say and Ord. *Neotoma floridana* is today indigenous to extreme southern Indiana.

Age and Environment

The fauna recovered from the Monroe County site indicates an early Late Pleistocene origin. Of the species recovered, *Ursus americanus*, *Canis lupus*, and *Canis latrans* are extant. Of the extinct animals of this fauna, *Canis dirus* is considered by Schultz (17) to be of Late Pleistocene age. Slaughter (20) gave the range of *Smilodon fatalis* as Middle Pleistocene to earliest Wisconsinan. The overlap in age ranges of elements in this fauna, plus the decidedly modern aspect of the fauna, leads me to conclude that the age must lie within the Sangamonian to Early Wisconsinan interval (i.e. early Late Pleistocene). This age assignment is supported in part by radiocarbon dating performed by Geochron Laboratories. Geochron reported no radiocarbon activity above the level of their counter background for carbon obtained from the apatite fraction of my material. This places the age of the deposit as earlier than 34,460 radiocarbon years before present. According to Flint (3), this dates the material as Middle Wisconsinan or older.

The enivronment represented by this assemblage is of considerable interest because the site lies close to the southern boundary of Late Pleistocene glacial activity in Indiana. Determination of the environment in which the gryke deposit was laid down should give clues to whether we are dealing with deposits of a glacial or interglacial stage.

The environment is interpreted herein as a grassy upland with scattered stands of trees. *Canis dirus* is believed by various workers, Schultz (17), to have been an inhabitant of open plains country. Similarly, many *Smilodon* remains (e.g. at La Brea) are interpreted as having inhabited open grassland environments. Ray, Denny, and Rubin (16); Slaughter (20); Lundelius (13); and Brown (1) believe that *Platygonus* occupied a similar environment to that of *Canis dirus* and *Smilodon*. Ray, Denny and Rubin (16) support this by referring to *Platygonus* ". . . faunal associations, wide distribution in the United States including the Plains and Far West, occurrence in loess, relative abundance, and apparently gregarious habits (frequent occurrence of multiple individuals)." In contrast, they point out that during the Late Pleistocene the solitary peccary *Mylohyus* probably occupied the woodland niche. In addition, the modern examples of *Canis latrans* and *Canis lupus* also inhabit open plains territory (Burt and Grossenheider, 1964), although not to the exclusion of other environments. Also, *Neotoma* may be found in grassy environments although Burt and Grossenheider (2) state that *Neotoma* is relatively tolerant of a wide range of climates and vegetation types and that this genus is fond of bluff ledges and crevices.

One member of this fauna, however, was probably not a typical inhabitant of plains. *Ursus americanus* is reported by Burt and Grossenheider (2) as presently inhabiting forests, swamps and mountains.

The preponderance of animals interpreted as inhabitants of open plains country, and the abundance of *Platygonus*, which almost certainly was restricted to such an environment, leads one to conclude the probable existence of such an environment surrounding the Monroe County site. Broken tree cover probably explains the existence of *Ursus americanus*. Guilday (6) gave a similar interpretation for a Late Wisconsin fauna from central Kentucky. This fauna contained, among other elements, *Platygonus compressus*, *Canis dirus* and *Ursus horribilis*. He interpreted the total association as boreal semi-prairie or parkland.

The temperature of the environment was probably warmer than at present. The best temperature indicator in the fauna is *Platygonus*. Most researchers have held that *Platygonus* is a warm-climate indicator. This is supported by present distributions of peccaries and faunal associations of fossil finds. However, Ray, Denny and Rubin (16) reported *Platygonus compressus* in drift of Wisconsinan age which they believed indicated that the animal had died within a few miles of the margin of a wasting Late Wisconsinan glacier. They believed that the presence of *P. compressus* indicated expansion of an open-country habitat at the expense of woodland rather than the presence of a warm climate. The suggestion that *P. compressus* ranged from a non-glacial warm climate to a periglacial cold climate is supported by a possible northward clinal size decrease (a negative Bergmann's response) in Wisconsinan age *P. compressus*. If this clinal size decrease is real, and if *P. vetus* was governed by similar environmental parameters as *P. compressus*, then the Indiana site may record a very warm environment, indeed, owing to the large size of the *Platygonus* specimens from the Monroe County site. No other good climatic indicators are present in the fauna.

The sum of the faunal evidence indicates that the Monroe County site records existence of an open grassy plains environment in southern Indiana. This environment would correspond to a dry period which could be either glacial or interglacial. Evidence for the latter has been stated above. Unfortunately, the evidence for a warmer climate is not conclusive. Until further evidence comes to light, delimitation of the Monroe County site as either Sangamonian or Early Wisconsinan must remain indeterminate. Palynological study of this deposit might help to answer this question and also verify my conclusion that the site was in a predominantly open grassland.

Origin of Fossil Deposit

The concentration of vertebrate remains within this deposit most probably represents accumulation in a natural death trap, although activities of wood rats probably added material to the assemblage.

The proclivity of wood rats for the acquisition of bones and teeth is well documented. For example, Olsen (15) described a fossil site which most probably represents the personal collections of many generations of wood rats. In most ways, however, the Monroe County site does not compare at all favorably with the Olsen site. For example, fossils at the former site are strongly biased towards carnivores and peccaries. Presumably, wood rats were not selective in their acquisitions. Consequently, one would not expect to see any bias in the record of a fossil site that was the result of wood rat activity and this interpretation is ruled out. Nonetheless, at this site one might expect to see a few skeletal remains of animals which were probably not susceptible to entrapment within a death trap of this kind and which can best be interpreted as resulting from wood rat importation.

Many animals, however, probably were susceptible to such entrapment. It is well known that *Platygonus* had an affinity for holes or fissures exposed to the surface. Other workers have postulated that similar concentrations of groups of *Platygonus* individuals found in circumstances similar to that of the gryke represent entrapment within a natural prison (e.g. Simpson (18), Gidley and Gazin (5)).

For several reasons a death-trap interpretation is very attractive for the Monroe County deposit. Such an interpretation helps to explain the unusual concentration of carnivores. It is not difficult to imagine a saber-tooth cat or one or two wolves from a pack being enticed into such a trap by the distressed squeals of a doomed peccary. Such an entrapped animal would seem to represent an easy meal. And even if the trap was ineffective for such an animal as a great, leaping saber-tooth, the cat might have found itself in grave straits when confronted by a seemingly unhealthy, but in reality very healthy and very large, peccary. Such a peccary could unquestionably inflict a wound that could doom the great predator to the same grave as its victim.

In order to be viable, the death-trap interpretation for the Monroe County site needs only a mechanism of allurement. Animals could have been enticed to enter the trap in several ways. First, some species might have been lured into the trap in the quest of shelter or water (assuming pools formed occasionally within the gryke). Secondly, some of the carnivores might also have been carrion feeders and have been trapped during their quest for earlier victims of this death pit. Young and Goldman (22) stated that wolves are well known as carrion feeders, which is true of most of the larger North American carnivores.

The question of carrion feeding also brings up one possible explanation for the common occurrence of *Platygonus* in such traps. If *P. vetus* and other *Platygonus* species were at least part-time carrion feeders, they may have been drawn to such death traps in the quest of food. The possibility of carrion feeding provides a ready explanation for the concentration through time of a large group of individuals at one locality by perpetuation of the mechanism of entrapment. Such a mechanism would yield a biased sample which would be weighted toward susceptible carrion feeders and carnivores, with the occasional or rare entrapment of other species that were seeking water or shelter.

The death-trap interpretation also helps to explain the intense disarray of bones in the deposit. Sedimentation here was sufficiently slow to permit complete decay of carcasses. Bones probably lay within the gryke and became brittle during extended periods of exposure. Periodic entry of more carrion feeders, including rodents, could have contributed to disarticulation of the skeletons and breakage of individual bones.

Whether carrion feeders could be totally responsible for the disarray of the deposit is indeterminate. Periodic flooding by heavy rains might have agitated the remains to some extent. However, there is no evidence that a stream ever flowed into or through the fissure. Sediments or stratigraphic features indicative of streams or the fauna associated with them (e.g. turtle or mollusc remains) are not present. In addition, few specimens show evidence of transport. Those that appear abraded may be the result of rodent gnawing.

Other explanations for bone concentration at the Monroe County site are not as attractive as the death-trap hypothesis. The only other plausible interpretation involves use of the gryke as a natural shelter for carnivores. The problem with this interpretation is the numerical bias among the fossils recovered. The unusual concentration of carnivores could be explained by this concept but the lack of remains of any suitable prey, other than *Platygonus vetus*, cannot. If large carnivores were using this site as living and eating quarters, a greater variety of large prey animals would be expected. Because my report is based only on partial excavation of the total deposit, the possibility that remains of other large prey animals are present cannot be excluded. Nonetheless, a considerable amount of material has been recovered and searched during the preparation of this report. Based on the results of this work, interpretation of the site as a carnivore shelter is rejected tentatively.

Another possible interpretation for the remains at the Monroe County site is that this gryke did not act as a prison for all animals which entered it, but only for some. According to this hypothesis, some animals might have frequented the cavity as a place of shelter. Such an hypothesis is difficult to evaluate because the exact nature of the gryke entrance or size is indeterminate owing to partial destruction during highway construction.

It seems clear, however, that the fissure was of somewhat different size or shape in the past. This conclusion is based on the preponderance of St. Louis Limestone detritus within this Salem Limestone gryke. It should be recalled that at present the St. Louis Limestone is not preserved directly adjacent to the gryke although St. Louis beds do overlie the Salem Limestone in the cuts on the far side of the new highway. The St. Louis detritus indicates that a mass of St. Louis Limestone must at one time have bordered directly the edge of the cavity. Significant lateral transport of St. Louis clasts is precluded because none of the fragments show much evidence of such transport. Furthermore, large boulders of the St. Louis that have been recovered from the gryke deposit could not have been transported far. The lack of Salem Limestone fragments in the deposit suggests that this unit was protected from any surficial weathering that would have produced large Salem clasts.

It is possible that the presence here of St. Louis clasts resulted from collapse into the gryke of deposits formed earlier in a topographically higher cavern within the St. Louis. This appealing hypothesis helps to explain the intensely jumbled character of the bone-bearing deposit. It seems clear, however, that such a considerable amount of required overlying rocks units could not have been removed so completely by erosion in the time that has elapsed since deposition of the bone-bearing material. For this reason, I reject the hypothesis of redeposition by collapse of a St. Louis Limestone cave system.

I conclude, therefore that we are dealing here with the preserved portion of the original site of bone accumulation. Further, at this site the Salem Limestone lay under a protective mantle of St. Louis Limestone. This view would require a somewhat different climate than is present at the site today. A mantling layer of St. Louis Limestone along the border of the fissure could protect the Salem from mechanical weathering but not from chemical weathering unless a somewhat drier climate prevailed than is present at the site today.

Summary and Conclusions

On the basis of the present study I envision for the bone-bearing deposit the following scenario. Sometime within the early Late Pleistocene a parkland environment prevailed in southern Indiana. Across this open grassy country, typical carnivores of the period hunted among other animals, notably large peccaries. Peccary herds periodically fell victim to a natural death trap in the form of a cavity that afforded no escape. In doing so, they enticed carnivores and carrion feeders to a similar doom. Living within the cavity, woodrats periodically carried in additional material from surrounding areas. Eventually the cavity was filled with clayey deposits and preserved as seen today.

Other clay-filled fissures are exposed along this stretch of Indiana Highway 37 and hold promise for similar fossil discoveries. Even if these other fissures did not serve as death traps during exposure to the surface, they may have accumulated remains of animals which used the fissures for shelter or which were washed or carried in after death. Whether these other fissures were open to the surface concommitantly or at different times is indeterminate. None of the adjacent fissures have been excavated but all have been given cursory examination, with no positive results to date.

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A Socio-Economic Impact Analysis of the Brookville Reservoir in Southeastern Indiana

LOIS E. NELSON and GARY W. BARRETT
Institute of Environmental Sciences
Miami University, Oxford, Ohio 45056

Abstract

The impact of the newly created Brookville Reservoir on the residents of Franklin County, Indiana, was investigated. In order to analyze community values, attitudes, and expectations, 600 questionnaires were hand-delivered to 12% of the households in the county. The rate of return was 33%. Findings indicated that automobile traffic problems ranked first among the public's concerns, while quality of roads and bridges ranked second. The preservation of farmlands and open space, the maintenance of natural beauty and wildlife areas, and the retention of noise and air quality ranked third, fourth, and fifth, respectively.

In order to evaluate the needs and expectations of visitors attracted to the Reservoir, 560 card questionnaires were distributed at the Mounds Recreation Site (containing beach, camping, and boating facilities) on a typical four-day summer weekend (17-20 August 1975). The rate of return was 82%. Sixty-eight percent of the visitors rated the roads in the vicinity of the Reservoir "good"; 61% indicated that they were there for one day only. Preferred activities were as follows: swimming—67%, picnicking—46%, and sightseeing—44%. Residents of Ohio and Indiana constituted 55% and 40% of the visitors, respectively. These data are important as a planning tool for the residents of Franklin County and the Indiana Department of Natural Resources.

Introduction

The Study Site

The Brookville Reservoir is a sixteen-mile-long, 7,790-acre (3,167 ha) reservoir located in Franklin and Union Counties in southeastern Indiana. It was constructed by the U. S. Army Corps of Engineers between 1965 and 1974 for the purposes of flood control, water storage, and recreation (7). Filling of the reservoir began on 1 January 1974; therefore, the summer of 1975 was the first recreational season that people began to use the facilities in significant numbers. The dam is 1.5 miles (2.4 km) north of Brookville, Indiana (population 3000). Brookville is the county seat of Franklin County (population 17,000) and the largest community in the immediate vicinity of the Reservoir (Fig. 1).

Franklin County is one of eight counties that make up the Historic Hoosier Hills Area of Southeastern Indiana. The Hoosier Hills Executive Council is interested in resource conservation and development and is highly aware of the four million people that are concentrated in nearby metropolitan areas such as Indianapolis, Louisville, and Cincinnati (Fig. 1). Their basic study (4) provided background data (e.g., soils, watersheds, and population distribution) for the present investigation.

Research Objectives

This study focused upon the socio-economic impact of the Reservoir upon the residents of Franklin County. Much data about conditions prior to 1965 were lost during the decade of construction. Thus, we felt that it was important to gather accurate data regarding people's values, attitudes, and expectations as the Reservoir began to produce impact on the various publics within the area (1).

Although several studies have been concerned with the impact of a reservoir on a defined geographical region (3) (6), most investigations have failed to focus on the socio-economic factors of such a facility and their effect on the populace of a rural area. Such was the major objective of this study.

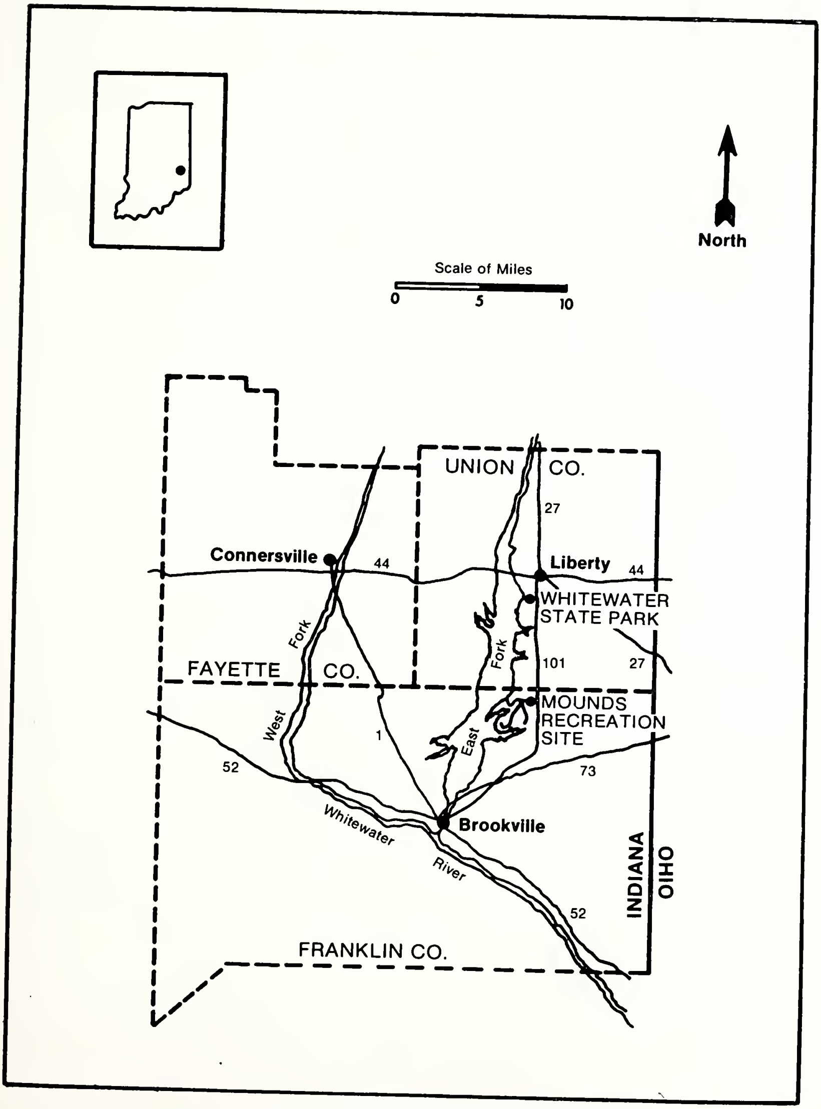
North
Scale of Miles
0
5
10
UNION CO.
27
Connersville
44
Liberty
44
WHITEWATER STATE PARK
Fork
Fork
101
27
FAYETTE CO.
MOUNDS RECREATION SITE
West
1
East
52
73
Brookville
Whitewater
River
INDIANA
OHIO
52
FRANKLIN CO.

FIGURE 1. *Map of the Brookville Reservoir and environs.*

Further, few studies have attempted to reconcile tourist needs and wants with those of the host community (5). Another objective of the study, therefore, was to assist the residents of Franklin County in communicating their collective desires for the area so that effective coordination can result in the satisfaction of both groups.

Methodology

The present investigation was conducted from 1 June to 31 December 1975. Specific objectives that guided the study were: (a) to analyze community values and expectations (via a questionnaire); (b) to identify and discuss relevant alternatives open to residents and special interest groups (via workshops); (c) to determine the needs and expectations of visitors to the Reservoir (via a questionnaire); (d) to identify areas of agreement and of disagreement between county residents and the tourists; and (e) to make recommendations that will attempt to coordinate or to make compatible the needs and desires of both publics. Objectives a and b were carried out as part of a group project (2).

The Community Survey

A public opinion survey was employed to obtain county-wide information concerning opportunities the Reservoir might provide and conditions which could evolve due to its presence. A six-page questionnaire was randomly hand-distributed in an effort to increase the rate of return by introducing ourselves to the respondents and by briefly explaining the reasons for conducting the survey. Three days (13-15 July 1975) were spent distributing 600 questionnaires to approximately 12% of the households in Franklin County. Responses were returned in business reply envelopes. Details regarding questionnaire format and sampling technique have been previously described (2).

Sections 1 through 5 of the questionnaire were classification questions designed for response stratification according to place of residence or age class. These were followed by a "semantic differential" section designed to determine how residents perceived the area. The next two queries were designed to learn how many Franklin County residents were using the Reservoir, what activities they engaged in, and which Reservoir sites they frequented (a map was included to assist them in locating these sites). Sections 9 and 10 focused upon the ranking of factors that characterize the area and of possible environmental and socio-economic changes that the presence of the Reservoir might produce. Comments and suggestions were also requested. The questionnaire was color-coded for each classification in order that differences of opinion relating to proximity to the Reservoir site could also be detected.

The Tourist Survey

The Army Corps of Engineers has a policy of taking a "visitors survey" at each of its facilities every three years (Mr. Mike Graham, Head Ranger. U. S. Corps of Engineers, Louisville District, personal communication). From 8 a.m. to 8 p.m. on a non-holiday weekend (Thursday through Sunday), each vehicle that enters representative sites is stopped for survey purposes. The Indiana Department of Natural Resources granted us permission to hand out the tourist questionnaire during the same weekend (17-20 August 1975). Five hundred sixty (560) questionnaires were distributed at the entrance to the Fairfield beach, the Templeton Creek boat ramp, and the Mounds camping site, collectively known as the Mounds Recreation Site (Fig. 1). The Mounds Recreation Site represented the best locale for a survey because: (a) it is the entrance to the only public beach, the main public camping area, and one of the nine boat ramps (i.e., the sample population represented a good cross-section of visitors); (b) it is the location of a gatehouse where all vehicles had to stop to pay an entrance fee and could be handed the questionnaire; and (c) it was one of the Corps survey sites, allowing for comparison of data.

The tourist questionnaire was designed to sample the needs and expectations of visitors to the Reservoir. An adult in each vehicle was asked to answer the questions and to deposit the card in a marked container as they exited the facility. Questions dealt with the following matters: opinion of the roads in the vicinity of the Reservoir; money spent each day while in the Reservoir area; reason for visiting the Reservoir; activities engaged in; what additional facilities might be desired; and point of origin. The tourist questionnaire was constructed to provide information that could be related to the community questionnaire.

The weather during the survey period was partly cloudy with light showers on Friday and Sunday. The temperature range was a consistent 18° C low and 31° C high.

The Corps surveyed 3749 vehicles during the four-day period, involving approximately 10,000 people (Mr. C. Hardison, District Engineer, U. S. Corps of Engineers, Louisville District, personal communication). As a basis for comparison, the peak day of the Fourth of July weekend saw 12,631 vehicles at the Reservoir and the totals for the month of August 1975 were 54,876 vehicles and 191,203 people (Mr. Graham, personal communication).

Computer facilities at Miami University were used for statistical analysis. The Statistical Analysis System (SAS) was utilized which provided frequency and percentage analyses for each question.

Results and Discussion

Community Response

The rate of return for the community questionnaire was 33% (i.e., 200 out of 600 distributed). Community questionnaire data revealed that the automobile traffic problems were the major concern (Table 1). "Traffic safety" and "quality of roads and bridges" were ranked 1 and 2, respectively, in the county totals. In the breakdowns these concerns were amplified: 7 out of 10 categories ranked "traffic safety" first, with high averages in Brookville and Brookville Township. This locale bears the brunt of the traffic bound for the Reservoir. All classifications ranked "traffic safety" 1, 2, or 3 except those under 20 years of age who ranked it 6. The same pattern held true for "quality of roads and bridges." The

TABLE 1. *Rank order of responses to questions about community values (2).*

		County	Brookville	Brookville Township	Town	Farm	Rural Non-farm	Under 20	20-30	30-40	40-50	Over 50
Traffic safety	Rank	1	1	1	1	2	1	6	3	1	1	1
	Avg.	5.9	6.3	6.3	6.0	5.9	5.9	5.5	5.9	6.2	6.2	5.8
Quality of roads and bridges	Rank	2	2	2	2	1	2	1	1	6	3	2
	Avg.	5.9	6.3	6.2	5.8	6.1	5.8	6.3	6.2	5.9	5.9	5.7
Farmlands and open space	Rank	3	4	8	6	3	6	7	5	4	6	3
	Avg.	5.5	5.9	5.2	5.5	5.5	5.4	5.5	5.6	5.9	5.8	4.9
Maintenance of natural beauty & wildlife areas	Rank	4	6	3	5	4	7	3	2	2	7	7
	Avg.	5.4	5.8	5.8	5.7	5.2	5.3	6.2	6.1	6.1	5.5	4.6
Noise and air quality	Rank	5	4	6	3	8	3	4	6	8	5	4
	Avg.	5.4	5.9	5.5	5.7	5.1	5.5	6.1	5.5	5.8	5.9	4.7
Clean city water supply	Rank	6	3	4	4	7	5	1	8	8	4	4
	Avg.	5.4	6.2	5.6	5.7	5.1	5.4	6.3	5.2	5.8	5.9	4.7
Public schools	Rank	7	7	7	8	6	4	8	4	3	2	8
	Avg.	5.4	5.6	5.4	5.3	5.3	5.5	4.9	5.8	6.1	5.9	4.3
Maintenance of small town or rural atmosphere	Rank	8	9	5	7	5	8	11	7	7	8	6
	Avg.	5.2	5.1	5.6	5.5	5.3	5.0	4.2	5.4	5.1	5.5	4.7
Historic landmarks	Rank	9	8	11	9	10	10	9	10	5	10	10
	Avg.	4.7	5.3	4.2	5.1	4.2	4.9	4.8	5.0	5.9	5.2	3.9
Appearance of business district	Rank	10	10	9	11	9	11	10	11	11	11	9
	Avg.	4.6	4.9	4.9	4.8	4.5	4.4	4.7	4.9	4.9	4.2	4.3
Recreation and parks	Rank	11	11	10	10	11	9	5	9	10	9	11
	Avg.	4.5	4.7	4.7	4.9	4.1	5.0	5.7	5.1	5.2	5.3	3.2

fifth ranked item—"noise and air quality"—was also related to the traffic situation and indicates the concern of a rural populace when suddenly inundated with urban traffic problems.

Table 2 summarizes how Franklin County residents regard certain developments that might occur as the tourist trade accelerates. These data indicate that county residents are eager for the economic opportunities that the Reservoir might attract to their area. Interestingly, unemployment stands at 8.8% (a 3-month average) and there is a scarcity of job openings for young people (2). However, the Reservoir has mostly seasonal employment to offer, and much of that is at the low-skill level (e.g., lifeguards, boat ramp attendants, and fee collectors). Real economic progress for the area depends on long-range planning. The data in Table 2 provide significant guidelines for all local and regional planning bodies involved with Franklin County as well as for state agencies (e.g., Indiana Department of Natural Resources) interested in impact analysis within a rural environment.

TABLE 2. *Franklin County community response to possible growth and development associated with the Brookville Reservoir (2).*

	Desirable	No Opinion	Un-desirable
Community growth and development	73.1%	17.4%	9.5%
Industrial development	68.5%	13.7%	17.8%
Shopping center	63.7%	17.9%	18.4%
Development of commercial businesses along Route 101	56.8%	29.6%	13.6%
Lakeside resort facility	55.1%	32.6%	12.3%
Summer home development	36.8%	37.8%	25.4%
Increased traffic along access routes	14.7%	23.7%	61.6%
Construction of billboards and signs	10.0%	20.2%	69.8%

Tourist Response

The rate of return for the tourist questionnaire was 82% (i.e., 457 out of 560 distributed). The tourist questionnaire asked visitors to rate "the roads you traveled on in the vicinity of the Reservoir" with these results: Poor—12%; Fair—20%; Good—68%. This opposite perspective was interesting and may be attributed to several causes. First, the phrase "in the vicinity of the Reservoir" was used in an attempt to get an assessment of county roads by visitors to match up with the assessment of local residents. The discrepancy may have arisen because visitors defined "in the vicinity of" too narrowly and only evaluated the new Route 101 (see Fig. 1) which is a new two-lane highway running up the east side of the lake between Brookville and Liberty, ignoring the old and narrow roads that brought them into the area. Second, since the survey site was on the east side of the lake, a preponderance of those sampled may have been unfamiliar with the old, rural roads that characterize most of the county. More importantly, it may be that tourists enjoy scenic, rural (county) roads and fail to recognize traffic patterns as congested in such an environmentally attractive setting.

The rationale for asking three specific tourist questions (i.e., length of stay, amount of money spent, and accommodations utilized by Reservoir visitors) was a desire to define the type of tourist which the Reservoir was attracting. These data are helpful to business people in Franklin County and to the various publics within the state.

In answer to the question "which best describes the main reason for your visit to Brookville Lake?," the answers were: one-day outing—62%; weekend vacation—17%; visiting in area as recommended by friend—9%; annual vacation—5%; and passing through area—5%. The assumption here was that those coming for only one day probably weren't driving more than 50 miles each way, while the small number who are taking their annual vacation represent those who conceive of the Reservoir as a place to come and stay for an extended time period.

Another question, "how much money do you estimate you spend each day when visiting the Brookville Lake area?" elicited these responses: under $10—70%; $10-$20—22%; $20-$30—4%; $30-40—1%; and over $40—3%. These figures bear a positive correlation to those from the question just discussed: i.e., the visitor-for-a-day (62%) spends under $10 (70%) and the few on annual vacation (5%) spend more than $30 (4%). Therefore, we recommend that future recreational plans be based on the short-term visitor.

In response to "what type of accommodations would you patronize?," tourists gave positive replies to: lodge on the lakefront—63%; restaurant along access routes—35%; shopping center—26%; restaurants in Brookville—21%; motels along access routes—12%; and hotel/motel in Brookville—4%.

The composite tourist is further defined by adding some data from the Army Corps survey (Mr. Hardison, personal communication). Visitors surveyed at several Reservoir entrances listed sightseeing as the most popular activity (45%) and boating as the second choice (21%). These two groups represent a majority of Reservoir users. Add to them the fishermen (14%) and the campers (10%) and the result is a large proportion of visitors who fail to patronize restaurants or motels. At a workshop held for area merchants, the difficulty of attracting tourists into town was stressed. These figures corroborate this opinion and are supported by new business activities evident along State Route 101 (e.g., camping supply stores, bait and tackle shops, and marine sales and service stores).

In summary, data from our tourist questionnaire and the Corps' survey describe the people currently visiting the reservoir as follows: 62% come for one day, 70% spend under $10 per carload, and 35% prefer to patronize businesses located out of town and along the access routes. These data suggest that the business peoples' apprehensions regarding the potential economic benefits from reservoir visitors are well founded.

The strong response to the "lodge on the lakefront" item (63%) merits further comment. A lodge is part of the state's long-range plan and this indication of client support for such a facility suggests that it should be moved to the forefront of the Department of Natural

Resources' plans for the Brookville Reservoir. A lodge would attract visitors with a different socio-economic basis than those currently visiting the lake and might have a positive impact on the business community within the county. The lodge is projected for the west side of the lake, close to Brookville, and should create a better balance of usage among the 13 entrances since only three are located on the west side.

Reservoir activities found to be most popular with visitors were as follows, based on 445 responses: swimming (67%), picknicking (46%), sightseeing (44%), motorboating (24%), camping (24%), fishing (23%), waterskiing (17%), hiking (9%), sailing (2%), and visiting the Treaty Line Museum (1%). When asked "what additional facilities would you like to see developed?," visitors responded: nature center—35%, expanded boat rental—27%, and marina—20%. These data suggest that the present reservoir facilities are too heavily weighted toward users who can afford to own the expensive equipment required for many of the popular activities (e.g., motorboating and waterskiing). The picnickers and sightseers might patronize a boat rental and nature center. These data can be utilized by the Indiana Department of Natural Resources in planning a well-balanced facility that offers recreational opportunities to all economic levels of the population.

Concluding Remarks

When the Corps and Department of Natural Resources personnel were interviewed early in the summer of 1975, they remarked that a great majority of Reservoir visitors were coming from Ohio. Mr. Dave Turner, Reservoir manager, said: "about 75% to 80% of the cars entering the facility carry Ohio license plates" and that "Indiana state officials had anticipated such high usage by people from Ohio." Questionnaire data revealed a somewhat different picture, however. In response to "where is your home?," respondents indicated: Ohio—55%, Indiana—40%, Kentucky—1%, and other—4%. People from Ohio were still in the majority, but not to the extent suggested by Reservoir personnel.

These findings demonstrate the need for planning along other than political boundaries (e.g., state lines). When a facility like the Brookville Reservoir is constructed, backed by a federal agency and using federal funds, planning needs to be conducted on a regional (e.g., OKI) or ecological (e.g., watershed) basis. When the regional or ecological concept is ignored, problems may arise that could have been prevented by taking a more comprehensive viewpoint.

Acknowledgments

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Post-Glacial Deltas in the Region of the Great Bend of the Wabash River

G. T. RICHARDSON and T. R. WEST, Department of Geosciences
Purdue University, West Lafayette, Indiana 47907

Abstract

Short-length, steep-gradient intermittent streams from three small drainage basins terminate in sand and gravel deltas in the Wabash River near Lafayette and West Lafayette, Indiana. The cause and effect of each delta was examined, as well as its influence on the environmental geology of the area. The small streams originate in ground-moraine uplands and flow across outwash into the Wabash River. The deltas were formed in two phases: the first accumulated slowly with little change in the river, and the second developed rapidly after urbanization of the area and resulted in an offset of the river channel. These deltas are part of a zone of similar landforms in the region of the "Great Bend of the Wabash." Environmental impact ranges from negligible to potentially harmful. The most severe instances involve loss of farmland and possible erosion of an abandoned landfill.

Introduction

This paper describes three deltaic accumulations in the Wabash River and their influence on the environmental geology of Lafayette and West Lafayette, Tippecanoe County, Indiana. Each delta is located where a short-length, steep-gradient tributary reaches local base level at the Wabash River. These dendritic tributaries have incised into Wisconsinan-age outwash terraces and ground moraine by normal erosional processes after cessation of glacial and glacio-fluvial deposition about 10,000 years ago.

The three deltas, their drainage basins, and the generalized surficial geology of the two-city area are depicted in Figure 1. Two drainage basins are located inside or adjacent to city limits, whereas the third appears located well beyond those political boundaries. However, this is not the case as urbanization has now encroached onto the headwaters of that drainage basin.

The overall view of the surficial geology for the study area (Fig. 1) shows a broad, evenly-undulating ground moraine dissected by a valley of large dimensions, now filled in part with great quantities of outwash sand and gravel. This valley is occupied by the Wabash River. The floodplain alluvium is a thin veneer of sand-silt-clay deposits of Holocene age.

This paper presents for the first time, specific physiographic place names that allow more descriptive detail for landscape features than was previously available in the Greater Lafayette area (Fig. 1). These designators were developed during an environmental geology analysis which considered, among other environmental concerns, the relationships of the three delta areas (4). These place names are particularly useful in delineating irregularly shaped landforms within the rectilinear Congressional Land Survey. Although topography is not shown in Figure 1, two distinct levels of partly-dissected outwash deposits represent former stages of the stream that drained the melting ice sheets. The upper level (Purdue Terrace and Wea Outwash Plain) and lower level

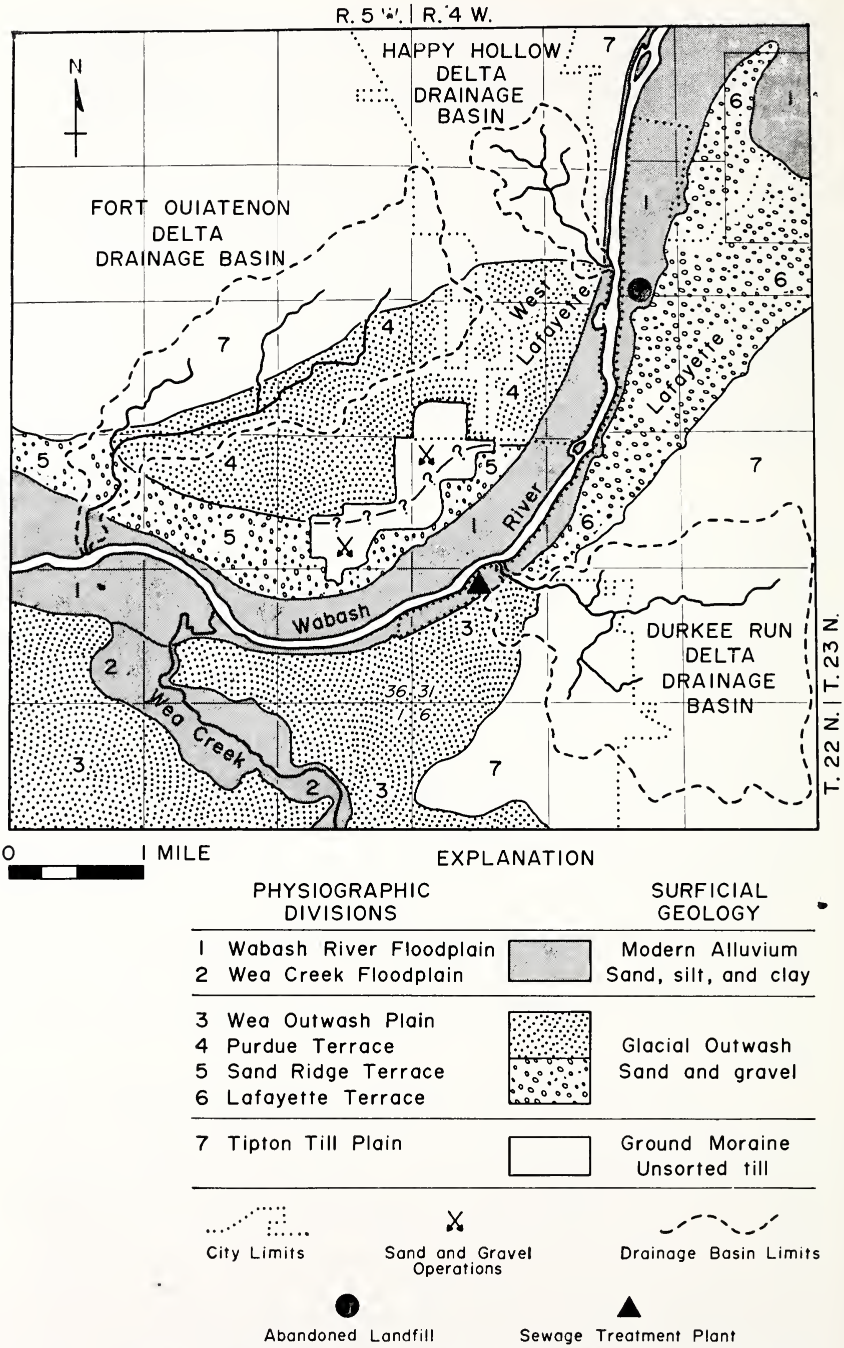
R. 5 W. | R. 4 W.
N
HAPPY HOLLOW DELTA DRAINAGE BASIN
FORT OUIATENON DELTA DRAINAGE BASIN
DURKEE RUN DELTA DRAINAGE BASIN
West Lafayette
Lafayette
Wabash River
Wea Creek
36 31
1 6
T. 22 N. | T. 23 N.
1
2
3
4
5
6
7
0
1 MILE
EXPLANATION
PHYSIOGRAPHIC DIVISIONS
SURFICIAL GEOLOGY
1 Wabash River Floodplain
2 Wea Creek Floodplain
Modern Alluvium Sand, silt, and clay
3 Wea Outwash Plain
4 Purdue Terrace
5 Sand Ridge Terrace
6 Lafayette Terrace
Glacial Outwash Sand and gravel
7 Tipton Till Plain
Ground Moraine Unsorted till
City Limits
Sand and Gravel Operations
Drainage Basin Limits
Abandoned Landfill
Sewage Treatment Plant

FIGURE 1. *Map showing physiographic areas, surficial geology, and limits of the drainage basins.*

(Lafayette Terrace and Sand Ridge Terrace) correspond to the Shelbyville and Maumee Terrace levels, respectively, as discussed by Thornbury (5).

Discussion of the Problem

Located along a six-mile reach of the Wabash River, the Happy Hollow, Durkee Run, and Fort Ouiatenon Deltas are terminal features of small-size tributaries whose long profiles, drainage basin size and average gradient are shown in Figure 2. These small drainageways originate on the Tipton Till Plain and have downcut through two levels of outwash materials bordering the Wabash River. For comparison, Wea Creek, whose long profile and statistics are also shown in Figure 2, flows across a landscape with identical physiographic conditions and terminates in a similar delta, yet affects the Wabash River to a much lesser degree than do the other streams. The significance of this difference will be discussed subsequently.

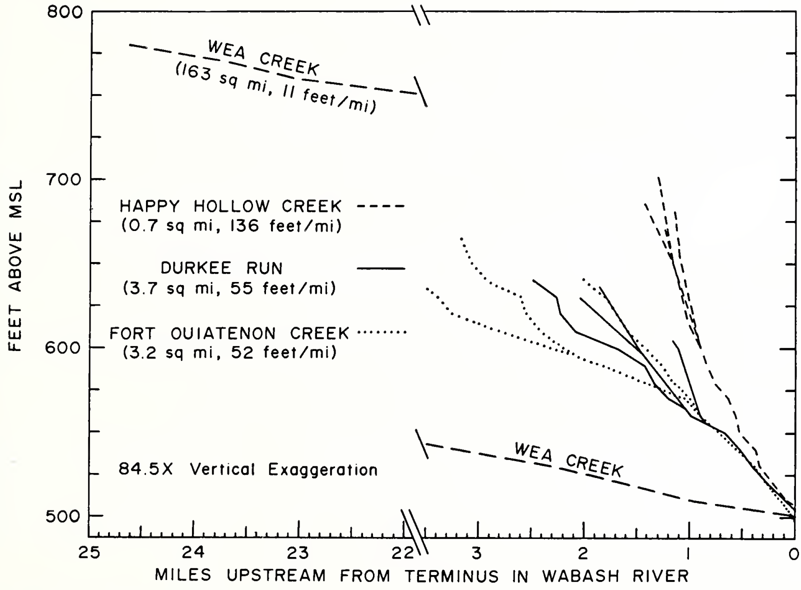

Figure 2. *Long profiles and drainage basin statistics for the streams terminating in deltas.*

During low water stages of the Wabash River, the deltas are seen to consist of two parts. The main body of each appears as a smooth, arcuate deposit of sand and gravel, covered with typical floodplain forest vegetation (willows, cottonwoods, and silver maples) and rising 2 to 5 feet above the river's surface. Near the upstream end of each main accumulation, an irregularly shaped secondary delta juts outward into the channel. These portions of the deltas consist also of sand and gravel (perhaps of somewhat coarser grain size than the main delta), but are devoid of vegetation except for pioneer species which take hold on the "new land" during extended low water stages. These secondary deltas are less than two feet above the lowest seasonal water levels and are easily inundated by minor fluctuations in the river. Figure 3 shows the outlines of the two portions of each delta and the channel contours opposite the delta. The secondary part of the Fort Ouiatenon Delta is not shown because it was submerged by a 1.7-foot rise of the Wabash River just prior to stream channel mapping.[1] However, some indication of its extent is shown by the channel contours. For each delta the bathymetric contours demonstrate the constriction of the upstream cross-section owing to the progradation of the secondary delta and development of a scour pool on the outside of the delta-influenced bend. Also shown in Figure 3 is the interpreted position of the Wabash River channel prior to offset by delta construction.

Channel contours downstream from the Happy Hollow Delta show a channel bar, in consequence of which a quarter-mile section of the Wabash River appears almost braided at low flow stages. This decrease in the river's ability to transport sediment is also observed downstream of the Durkee Run Delta. This is interpreted as an increase in bed load as a result of bank erosion and scour opposite the deltas. An additional change in sediment transport characteristics is represented by the fine sand and silt that covers the upper surface of each main delta. This change from the coarse, granular texture of the underlying materials suggests that the bulk of the main delta acts as a point bar (*i.e.*, reduces velocity on the inside of a river bend) at high water stages, a condition reinforced by the presence of vegetation which further reduces stream velocity and promotes rapid deposition.

A review of the historical airphoto coverage (1929-1975) shows similarities and differences concerning the three deltas and the attendant offset of the Wabash River. For all sites, the tree-covered main delta is visible on the earliest photographic record, and little or no change in outline has occurred to the present. At each location, the secondary delta apparently was already established at the time of the earliest photos. However, the extent and rate of river offset opposite delta progradation varies considerably for the sites as a function of time. Across from the Happy Hollow Delta, bank offset has been noticeable only since the early 1950's, whereas there has been little or no measureable change in the channel outline opposite Durkee Run Delta since the time of the first photographic record. Lateral migration opposite the Fort Ouiatenon Delta, although observable on the earliest photos, has been accelerating since the 1950's.

In the Happy Hollow and Durkee Run drainage basins, the photo record displays the dramatic shift from agricultural to urban conditions with the passing years. The increase in sediment yield into the streams during this land use change has been counteracted, to a minor degree, by an increase in forest cover in these two drainage basins. The present extent of forest in these areas is the greatest since the first

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[1] Drainage of an artificial lake for inspection purposes raised the river level above its previous low flow.

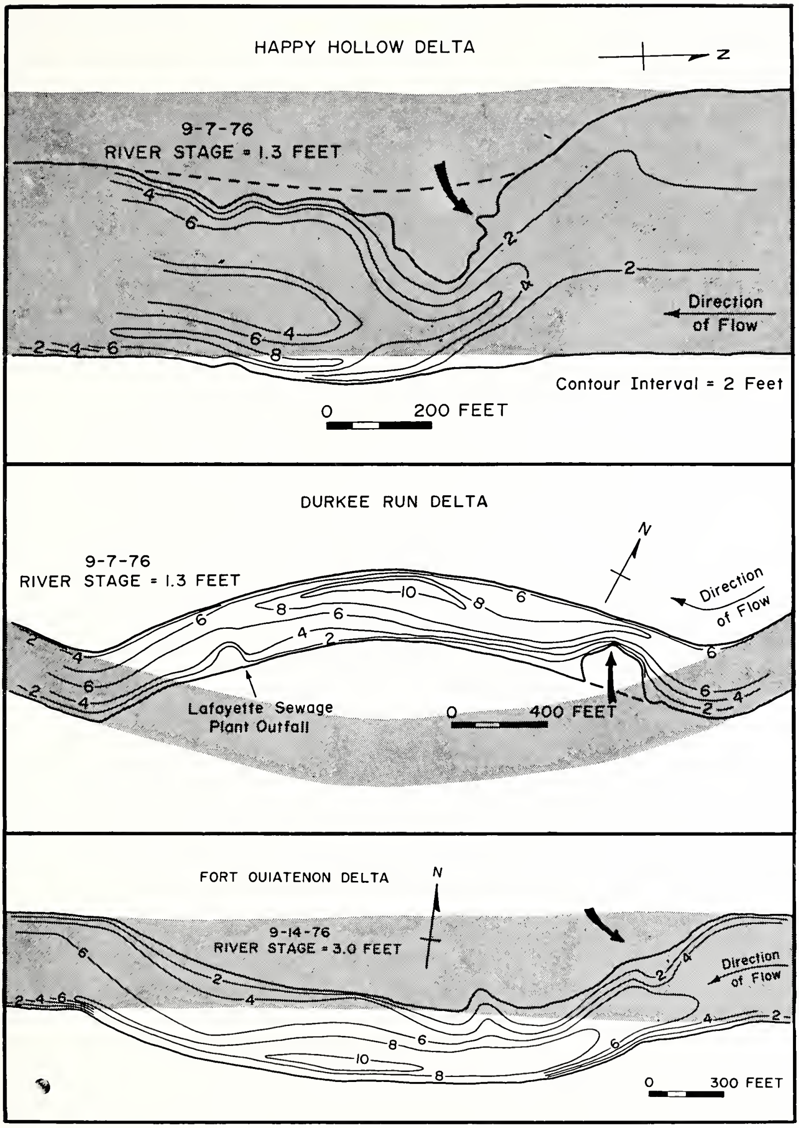
HAPPY HOLLOW DELTA
Z
9-7-76
RIVER STAGE = 1.3 FEET
4
6
2
2
4
Direction of Flow
6
4
8
2
4
6
Contour Interval = 2 Feet
0 200 FEET
DURKEE RUN DELTA
N
9-7-76
RIVER STAGE = 1.3 FEET
10
8
6
6
8
6
4
2
Direction of Flow
2
4
6
4
2
6
6
4
2
Lafayette Sewage Plant Outfall
0 400 FEET
FORT OUIATENON DELTA
N
9-14-76
RIVER STAGE = 3.0 FEET
6
2
4
2
4
6
8
6
10
8
6
2
4
Direction of Flow
4
2
0 300 FEET

FIGURE 3. *Channel contours opposite the deltas. Dashed line separates main and secondary deltas. Bold arrow indicates position of outlet for the tributary streams. Tinted area approximates the interpreted river channel prior to delta accumulation and offset.*

days of white settlement. Dos Santos and Miles (1) reported that urbanization within the Happy Hollow drainage basin has reached its maximum extent and future sediment yields are expected to significantly decrease. Within the Fort Ouiatenon Delta drainage basin, the actual area converted from agricultural to residential/commercial usage has been rather minimal; however, building has occurred on the steep slopes marking the transition from the Purdue Terrace to the Tipton Till Plain uplands. Thus this sloping land, which represents a minor portion of the drainage basin, has had a proportionately greater effect on erosion and stream deposition.

Environmental impact adjacent to the deltas is as varied as is their recent erosional history. Across the river and slightly downstream from the Happy Hollow Delta, a sanitary landfill was previously operated near the base of the Lafayette Terrace (see Fig. 1). Although operation ceased in early 1972, materials placed in the landfill are subject to exposure and removal during high water stages of the Wabash River. This is a consequence of the river offset opposite the Happy Hollow Delta which has removed a portion of the natural levee, allowing access to the landfill site and the adjacent floodplain. In contrast, no adverse impact has occurred opposite the Durkee Run Delta because this area is devoted to minor agriculture or vacant, fallow land. In fact, there is a harmonious land use on the main portion of the Durkee Run Delta, which is the site of the Lafayette sewage treatment plant. Surrounded by man-made levees, this site is well removed from the erosion on the opposite bank. At the Fort Ouiatenon Delta the Wabash River offset has resulted in the loss of some five or six acres of regularly-tilled farmland. An additional expense to the landowners at this site involved the excavation of a new drainage ditch. This was done to prevent severe erosion along a natural waterway ending at that portion of the river bank suffering rapid offset. If uncontrolled, such erosion would have denied access to an additional 20 or more acres of land and rendered them useless for crop production.

Based on field observations and historical airphotos, the following general account is offered as a history of formation for each of the deltas. After 1) the last glacial stage had deposited the local ground moraine, 2) meltwaters of the northward-receding ice mass had accumulated, reworked, and then dissected outwash sand and gravel into two major terrace levels, and 3) the climate began a trend towards present-day conditions, normal stream erosion commenced on the escarpments of the local terraces and the Tipton Till Plain. Rapid runoff from the small-size, steep-gradient drainages was thus established, leading to delta formation in the present-day Wabash River. Because of minimal sediment yields from vegetated slopes under pristine environmental conditions, the normal flow of the Wabash was able to accommodate the deltaic input and remove the excess. Thus no significant deflection of the river channel would have occurred. During this period, delta sediments shifted downstream from the initial outlet site and formed the large crescent-shaped areas visible today (main delta formation).

Since the coming of the white man to the area, there has been a shift in land use, climaxed by maximum agricultural tillage about 1920 (although decreasing steadily ever since) and a tremendous residential/urban expansion, starting in the 1940's and continuing to the present. These terrain disturbances sufficiently increased runoff volumes and erosion, resulting in deposition of the smaller, secondary deltas now seen prograding into the Wabash River channel. With establishment of these newer sedimentary deposits, the river was unable to transport the sediments and began to deflect around them. The redirected river current began to erode the alluvial banks opposite the secondary deltas, culminating in the present offsets across from the Happy Hollow and Fort Ouiatenon Deltas. In contrast, the progradation of the secondary Durkee Run Delta appears to have had little or no effect in initiating further erosion because the present offset at that site is nearly identical to that observed in the earliest photo record. Hence it can be predicted that a more-or-less naturally stabilized channel will develop. Periodically it may be subjected to new bank-caving and lateral migration, accompanied by rapid attenuation of the sinuosity of the induced offsets. The Wabash River seems unable to establish free meanders in response to the offsets.

From this interpretation of the local deltaic history, a question arises about how these features relate to the regional landscape. An initial check on such deltas in adjacent areas led to an examination of topographic maps of the Wabash River area along a reach of about 150 river miles upstream and downstream from the Greater Lafayette area. Based strictly on map evidence, Figure 4 shows the distribution of deltas relative to the varying geomorphic conditions of the Wabash River valley. Morisawa (3) presented a summary of factors resulting in soil erosion; these were climate, rainfall, soil character, vegetation, geologic materials, and topography. Applying Morisawa's generalized interactions to the specific conditions of this reach of the Wabash River, it is concluded that each factor has been more or less constant for the past few centuries. However, geologic materials and topography, combined with pronounced local changes in vegetation and land use, have produced a stream reach of delta formation within the region of the "Great Bend of the Wabash" described by McBeth (2).[2] This stream reach is characterized by local relief of 150 to 200 feet and juncture with short-length, steep-gradient tributaries which head on the glacial till uplands and intermittently discharge across the locally wide outwash terraces. Upstream from this reach, available relief diminishes to generally less than 100 feet and the Wabash River tends to follow or parallel its pre-glacial channel in bedrock; there is also less outwash material. Downstream from the "bend," where the total amount of outwash is greater, the old-age characteristics of the Wabash River valley (by Davisian standards) tend towards enlargement of the drainage basins of tributary streams, thereby reducing erosion because of greater basin storage and delayed runoff. Thus the resultant diminished flow is similar to that of Wea Creek in the Greater Lafayette area. Wea Creek (see Fig. 1) drains 163 mi^2 (44 to 233 times larger than the three drainage basins studied in this report) with a rather gentle average gradient (Fig. 2). It has, since glacial times, deposited a delta at its

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[2] McBeth's "Great Bend" is where the Wabash River starts to flow due south near the city of Covington, Indiana. The stream reach of delta formation for this report is that portion of the river flowing as a nearly straight line from northeast to southwest, from Logansport to Covington, although the specific physiographic conditions of this reach are typically found from Delphi to Williamsport.

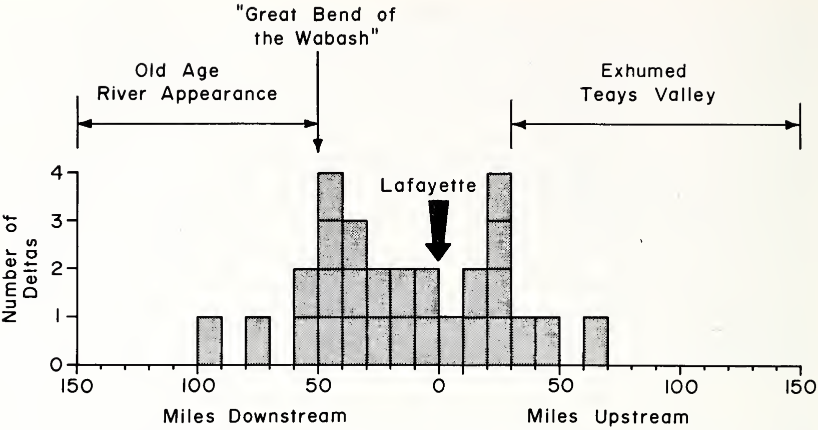

FIGURE 4. *Histogram showing the number of deltas upstream and downstream from Lafayette and the varying geomorphic conditions of the Wabash River valley.*

terminus in the Wabash River, but at a pace that has produced only a minor offset on the opposite river bank. This offset has remained nearly constant throughout the period of historical airphoto coverage.

Concluding Statement

Surface runoff is dependent not only on the quantity and rate of precipitation, but on other aspects, including topographic relief and infiltration rate of the surface layers. Stream discharge also is a function of the physical size of the drainage basin, with smaller areas showing a faster response to the same amount of precipitation. Smaller areas can also experience localized higher intensity storms. This yields, by comparison, a more delayed response for larger drainage basins. Particle size and volume of erodible material further determine the load a stream will transport as stream competence varies directly with discharge.

In this report three small drainage basins, ranging in size from 0.7 to 3.7 mi^2 (1.8 to 9.6 km^2), were examined in the Lafayette-West Lafayette area. Each drainage basin has as local base level the Wabash River, where a sand and gravel delta has been built into the channel of the larger river. These deltas are the result of intermittent, torrential streams originating on partly-urbanized, relatively-impermeable ground moraine and then flowing across abundant deposits of unconsolidated outwash sands and gravels. Each delta has two parts: a higher, vegetated area which is the main bulk of the sedimentary accumulation and a lower, non-vegetated secondary progradation extending farther into the river. In two cases, the secondary delta has initiated erosion of the opposite river bank by deflecting the current; there have also been changes in the channel characteristics. Negative environmental impact has ranged from negligible to potentially harmful, depending on prior land use.

One purpose of this report is to focus attention on the significance of landform features relative to environmental impact. In the examples cited, the relation and consequence of small deltas and land use has been examined. Each delta is the product of natural processes, intensified in part by man's influence; the cumulative effect is negligible where there is no interference with man's activities. In the past, only through hindsight have land use problems associated with such features been recognized. Realization of the potential effects of urbanization, increased runoff, erosion, sedimentation, landfill location, *etc.*, in connection with geologic features such as these deltas, could lead to a better understanding of our physical world, allowing for management towards a better local environment in the future.

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The Application of Remote Sensing Techniques in Microscale Climatology

S. N. Goward and J. E. Oliver, Department of Geography and Geology
Indiana State University, Terre Haute, Indiana 47809

Abstract

The climatological study of heat and energy budgets in urban areas has long proved problematic because of incomplete data sources. To meet this contingency this paper illustrates how the use of remotely sensed multispectral data allows evaluation of selected components of the energy budget. Using an area of Indianapolis as a sample region, instantaneous maps of surface albedo and infrared radiant characteristics are derived. Generation of representative cross-sectional energy profiles in selected electromagnetic bands point to the highly variable interface characteristics of the surface. It is concluded that microclimatic analysis using multispectral data holds great promise for quantitative evaluation of the urban energy balance.

One of the fundamental concepts of climatology concerns the energy and heat budget of the earth-atmosphere system. The absorption of solar energy by the earth system is fundamental to the form and function of the earth's climate. While the significance of the sun's role in climatology has been recognized since ancient Greek times, it was only during the last century that the basic physics of radiant energy and its interaction with material substances of the earth were identified (Budyko, 2). It has been shown that the physical properties of the materials present at the interface between the atmosphere and the hydro-lithosphere play a key role in determining amount of energy absorbed and the type of energy conversion from radiation to other forms of energy.

The simplest description of the heat budget is a symbolic expression which identifies the component energy conversions at the interface. This is given by:

$G = (Q + q)\,(1 - a) + I\downarrow - I\uparrow - H - LE - F$ where:

G = the energy change at any point of the interface
$(Q + q)$ = the sum of direct and diffuse solar radiation
$(1 - a)$ = the percent of shortwave radiation absorbed (a = albedo)
$I\downarrow$ = the longwave radiation emitted from the atmosphere toward the surface
$I\uparrow$ = the longwave outgoing radiation
H = sensible heat
LE = latent heat
F = advected heat

Note that terms in the equation which add energy to the interface are positive whereas terms that remove energy are negative. The object of this paper is to show how remotely sensed data can be used to quantify selected components of the energy flows indicated in the equation.

Quantifying Energy Flows

Measurement of energy flows has only slowly become technically feasible. The earliest measurement devices were simple glass lenses that burnt a paper chart to indicate the duration of intense sunlight. Recently, a variety of electrical and photochemical devices have been developed (Kondratyev, 3). The pyranometer and various radiometers have come into relatively common use in the United States since World War II (Miller, 4). The majority of energy budget studies have been conducted under the methodology developed for other meteorological observations (WMO, 5). A stand of instruments is set up at a selected location under the assumption that the measurements from this location are representative of a larger adjacent region. Unfortunately, this assumption is not strictly valid for heat budget measurements due to the varied nature of earth surface materials. In particular the complex pattern of surface materials in urban areas results in the impossibility of selecting a representative site from which to make such observations.

The most obvious solution to the problem of measuring the heat budget over differential surfaces is to make simultaneous observations over a representative sample area for each surface type (Bach & Patterson, 6). The cost of such a field network of observation stands is extremely high and cross calibration between instruments is never totally successful. Experimental research using aircraft mounted pyranometers and radiometers showed that such airborne measurements could be carried out (Kung, et al., 7; Lenschow and Dutton, 8). These early successes in airborne measurements and contemporary developments in space satellite technology led to the TIROS-NIMBUS-ATS meteorological satellite program (Barrett, 9). The sensors on these satellites measure the reflectance or albedo of the earth and longwave radiant emissions from the earth's surface and atmosphere. The spatial ground resolution of the early aircraft observation and current meteorological satellite observation is too gross (1 to 5 KM) to be used in microclimatic research. However, the spatial perspective of the data provide major insights into the global and regional variations of the energy budget of the earth (Lorenz, 10) and is suggestive of the methodology for energy budget measurements in microscale studies.

Multispectral Scanning

The measuring device that provides the answer to the need for microscale spatial quantification of the heat budget was not developed primarily for climatic research, but for the technical field of remote sensing. In recent years, under the stimulus of military surveillance, technology has advanced to the point that the camera and film are not required to produce an image. Light sensitive sensors are scanned across a scene to measure the variation of radiation flow across the scene. The scanner is calibrated to known light and thermal sources so that the data may be directly converted to physical measures of radiant intensity. The image is produced by sequentially viewing strips of the scene. The width of the strip determines the ground resolution of the scanner.

The majority of scanning sensors used in remote sensing research are multispectral which refers to the ability of the scanners to measure two or more different segments of the electromagnetic radiation spectrum simultaneously. The advantage in separating the radiation into spectral segments is that certain earth surface features can be easily identified by their response in certain segments of the electromagnetic spectrum. For example, healthy green vegetation reflects intensely in the near infrared (.7mμ-1.5mμ) due to the molecular structure of the vegetation. This spectral separation is a major advantage for climatic research. The shortwave radiation measured covers the wavelength range of the radiant energy emitted from the sun. The longwave radiation is generally measured in one or both of the two longwave radiation "windows" in the atmosphere 4.0mμ-5.0mμ and 7.0mμ-14.0mμ, the latter of which is centered on the peak intensity of radiation emitted by the earth's surface. Since there is little spectral overlap between these shortwave and longwave fluxes the sophisticated multispectral scanner with full spectral response capability provides simultaneous high resolution independent measurements of the reflectance of incoming solar radiation and of outgoing radiant emissions from the earth's surface. These radiant flows are the key factors in heat budget investigations. The synoptic view provided by the scanner allows investigation of microscale spatial variations in these key factors of the heat budget.

Available Sensing Platforms

There are a number of multispectral scanners in use today. The sensors on the TIROS-NIMBUS and LANDSAT satellites are types of multispectral scanners. As noted earlier the TIROS-NIMBUS data resolution is too gross for meso and microscale studies. The resolution of the LANDSAT data (80 meters) would be applicable to regional climatic analysis; however, the spectral range of the current satellites is too narrow (.5mμ-1.1mμ) to provide sufficient information about the surface energy budget. The sensors on future LANDSAT satellites will have increased spectral range including thermal infrared and may be well suited to mesoscale climatic analysis (NASA, 10). Other future satellite projects including the "Heat Capacity Mapping Satellite" show potential in climatic research.

Of more immediate interest are the multispectral scanners mounted in aircraft. One of the most sophisticated of these is the M-7 multispectral scanner developed and operated by the Willow Run Laboratories at the Environmental Research Institute of Michigan (ERIM). The ERIM M-7 multispectral scanner is a 12 channel instrument (12 spectral segments can be measured simultaneously, the spectral segments recorded may be determined by the researcher). The range of spectral sensitivity is from the ultraviolet (.4mμ) to the thermal infrared (14.0 mμ). There are 5 radiation calibration sources. Three for the visible and near infrared radiation range, two for the thermal infrared. When the sensing aircraft is flown at 600 meters (2000′), the ground resolution of the scanner is approximately 2 meters. For each square kilometer of the earth's surface observed from 600 meters, 250,000 independent contiguous measures of the radiation flux are collected. This detailed synoptic view of the radiation flux is ideally suited to the analysis of the microscale spatial variation of the heat budget of the earth's surface.

A Research Approach

Research is currently being pursued at the Remote Sensing Laboratory, Department of Geography and Geology, Indiana State University to further develop the application of ERIM M-7 multispectral scanner to heat budget studies. The ISU Remote Sensing Laboratory (ISURSL) is a research and applications facility which works in close cooperation with The Laboratory for Application of Remote Sensing (LARS) at Purdue University. ISURSL maintains a remote computer terminal to the LARS digital computer system. This facility provides ISU access to a wide range of aircraft and satellite multispectral data and numerous computer programs for processing and analyzing the data.

The study area for this research is a ¾ by 5 mile section of the Indianapolis, Indiana urban region. The long axis of the area follows the course of the White River where it passes through the western side of Indianapolis (Fig. 1). A wide range of urban land use is present in this region including commercial, industrial, residential and recreational activities. The ERIM M-7 scanner data collected from 600 meters on August 10, 1972 and on January 1, 1973 for this region are being utilized in this research.

In order to graphically demonstrate the measurement capability of the multispectral scanner and its applicability to climatic research calibrated data samples from a subregion of the research area for the data collected in August are presented (See Fig. 1).

Figures 2 and 3 are alphanumeric line printer maps of the subregion selected. Each alphanumeric symbol represents one picture element or pixel of the data. Each pixel represents an approximately 5x5 meter (15x15 feet) surface area from which radiant flows are measured. The total number of such measurements made in this approximately ¾x¾ mile area is 44,622. The scanner simultaneously measured 12 spectral components of the radiant flux for each pixel. Two of the spectral components are presented here. Note that in order to reduce the size of figures 2 and 3 every other line and column of pixels has not been displayed. For comparative purposes figure 4 provides an aerial photograph of the study area.

The data displayed in figure 2 are measurements of reflected solar radiation in the 0.55-0.60μm spectral region. They have been calibrated against known internal light sources to produce a simulated display of the percent reflectance of solar radiation from the surface in this spectral region. These data should not be viewed as accurate absolute measurements of percent reflectance or albedo of the surface. Research is still in progress to identify the relation between measured reflectance, incoming solar radiation and the calibration light sources in order to produce accurate percent reflectance-maps. The data in figure 2 have been qualitatively accessed as being accurate to ±10%. The data, however, well demonstrates the magnitude of the relative variance in surface reflectance. Man-made surfaces in general reflect a higher percent of incident solar radiation than natural surfaces. Exceptions are the roof of the ball park grandstand and the parking lot adjacent to the ball park.

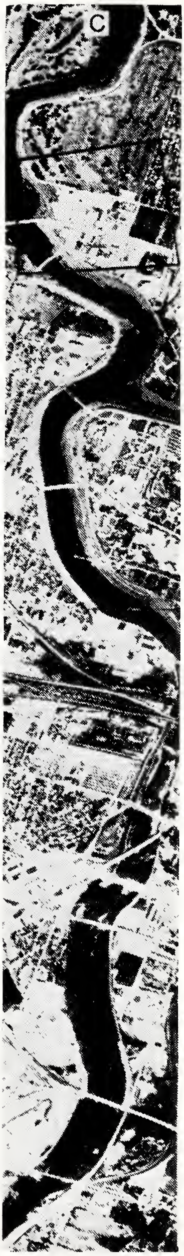

FIGURE 1. *A LARS digital (television) image of th study area in Indianapolis. 0.55-0.60um spectral data. Subregion displayed in Figures 2 and 3 and 4 delineated by the rectangle near the top of the image.*

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 FROM   11.4 TO  13.6 OISPLAYEO AS ¤                 CALI RATION COOE........... 4
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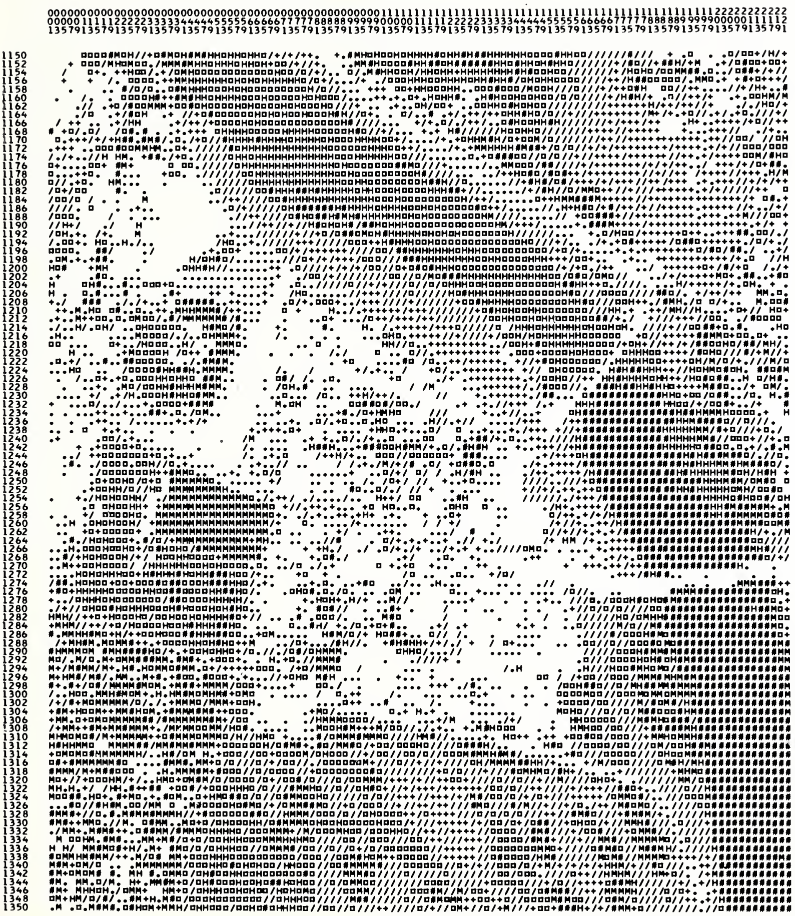

FIGURE 2. *An alphanumeric line printer map of simulated percent reflectance in the 0.55-060um spectral region.*

Figure 3 shows the radiant flux measured in the 9.30-11.7μm thermal infrared region. These data have been calibrated against the two thermal plates in the scanner and converted into radiant surface apparent temperatures. The conversion to surface temperatures is carried out by a non linear calibration function newly developed and implemented in the LARS computer system by the authors as an ongoing step in applying multispectral scanner data to climatological research. The

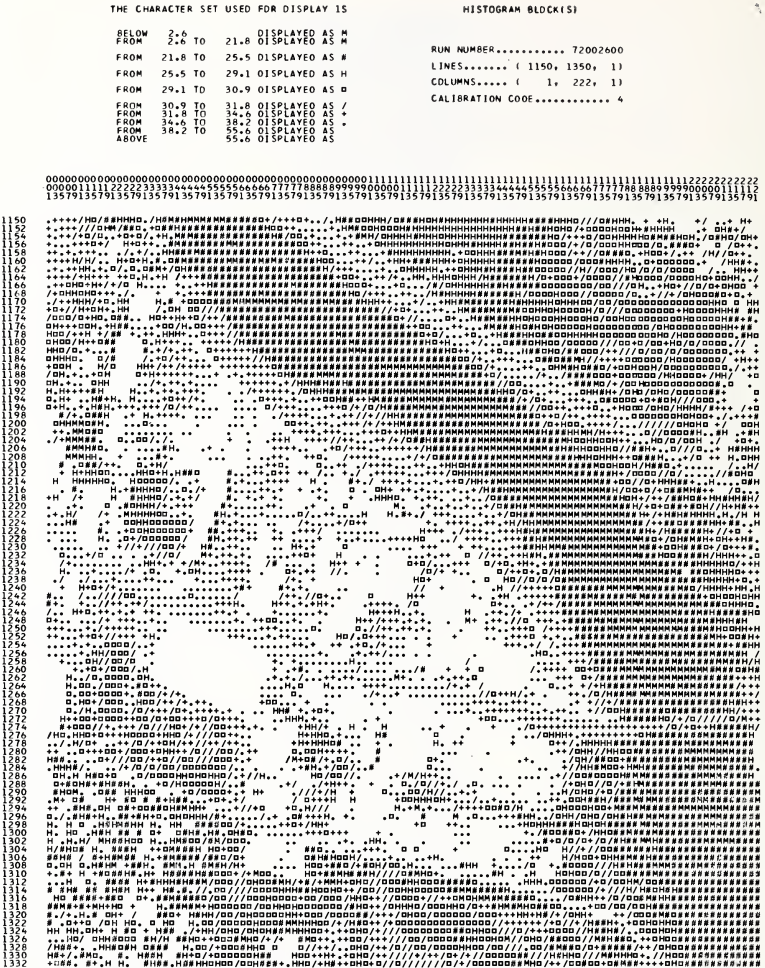

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FIGURE 3. *An alphanumeric line printer map of calibrated apparent surface radiant temperatures (°C) in the 9.3-11.7um spectral region.*

form of the nonlinear calibration function follows suggestions put forth in Bartolucci et al. (11). The accuracy of the measurement is within ±0.2°C. The highest temperatures are from man made surfaces with the exception of the metal roof to the left of the ball park. This is the result of the low emissivity of the material which markedly reduces the radiant emissions and therefore the surface apparent temperature. In general, the emissivity of the surface materials in the region is between .90 - .98 and does not significantly alter the relation between apparent radiant temperatures and actual kinetic temperatures.

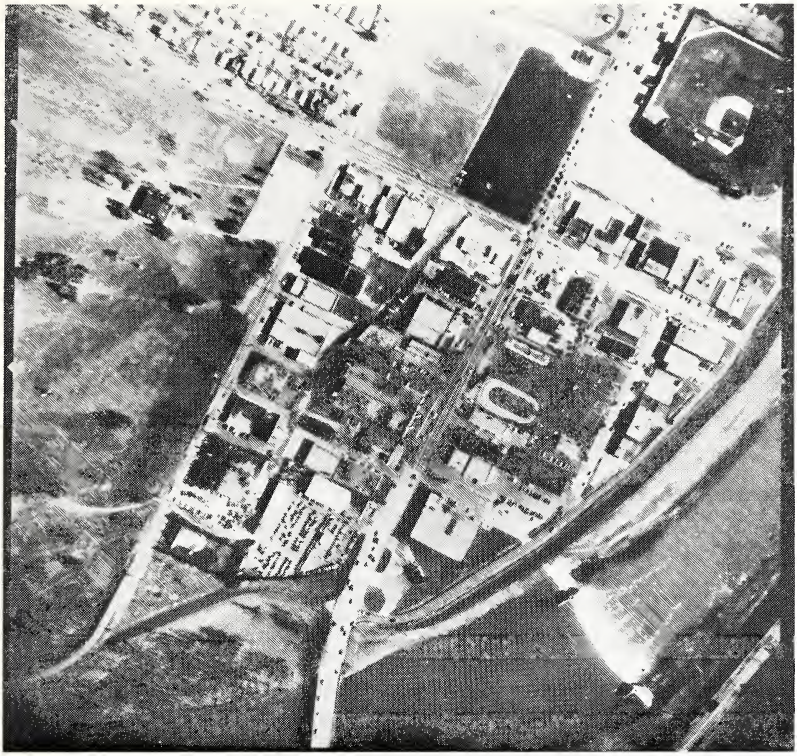
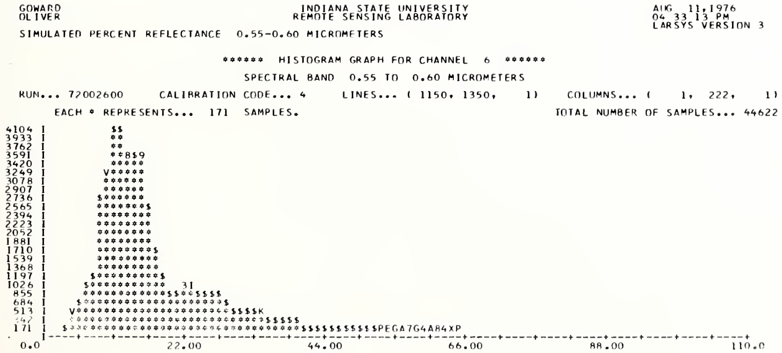
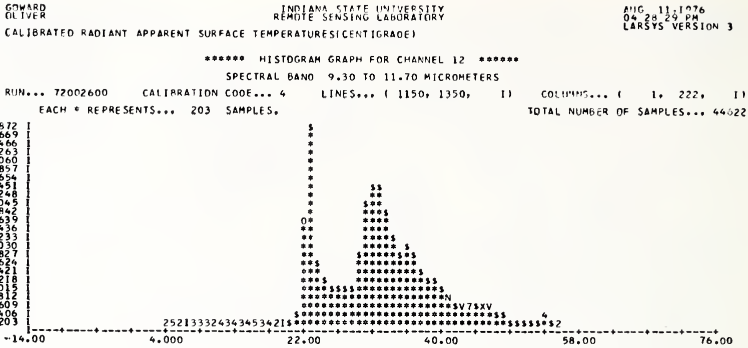


FIGURE 4. *A panchromatic aerial photograph of the region displayed in Figures 2 and 3.*



```
GOWARD                                         INDIANA STATE UNIVERSITY                              AUG  11,1976
OLIVER                                        REMOTE SENSING LABORATORY                              04 33 13 PM
SIMULATED PERCENT REFLECTANCE  0.55-0.60 MICROMETERS                                                 LARSYS VERSION 3

                              ******  HISTOGRAM GRAPH FOR CHANNEL  6  ******

                                  SPECTRAL BAND  0.55 TO  0.60 MICROMETERS

RUN... 72002600     CALIBRATION CODE... 4     LINES... ( 1150, 1350,    1)    COLUMNS... (    1,  222,    1)

     EACH * REPRESENTS...  171  SAMPLES.                                      TOTAL NUMBER OF SAMPLES... 44622

4104 I         $$
3933 I         **
3762 I         **
3591 I         **8$9
3420 I         *****
3249 I        V*****
3078 I        ******
2907 I        ******
2736 I       $******
2565 I       *******$
2394 I       ********
2223 I       ********
2052 I       ********
1881 I       ********
1710 I       ********$
1539 I       *********
1368 I       *********
1197 I      $*********$
1026 I     $***********  31
 855 I     ************$$**$$$$
 684 I    $********************$
 513 I   V**********************$$$$K
 342 I   ****************************$$$$$
 171 I  $*********************************$$$$$$$$$$$PEGA7G4A84XP
.    I----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+
  0.0                  22.00               44.00               66.00               88.00               110.0
```

FIGURE 5. *A histogram of the distribution of simulated percent reflectance in figure 2. 0.55-0.60um spectral region.*



```
GOWARD                                   INDIANA STATE UNIVERSITY                            AUG 11,1976
OLIVER                                   REMOTE SENSING LABORATORY                           04 28 29 PM
CALIBRATED RADIANT APPARENT SURFACE TEMPERATURES(CENTIGRADE)                                 LARSYS VERSION 3

                              ****** HISTOGRAM GRAPH FOR CHANNEL 12 ******
                                 SPECTRAL BAND  9.30 TO 11.70 MICROMETERS
RUN... 72002600     CALIBRATION CODE... 4     LINES... ( 1150, 1350,    1)    COLUMNS... (    1, 222,    1)
    EACH * REPRESENTS... 203  SAMPLES.                                      TOTAL NUMBER OF SAMPLES... 44622
```

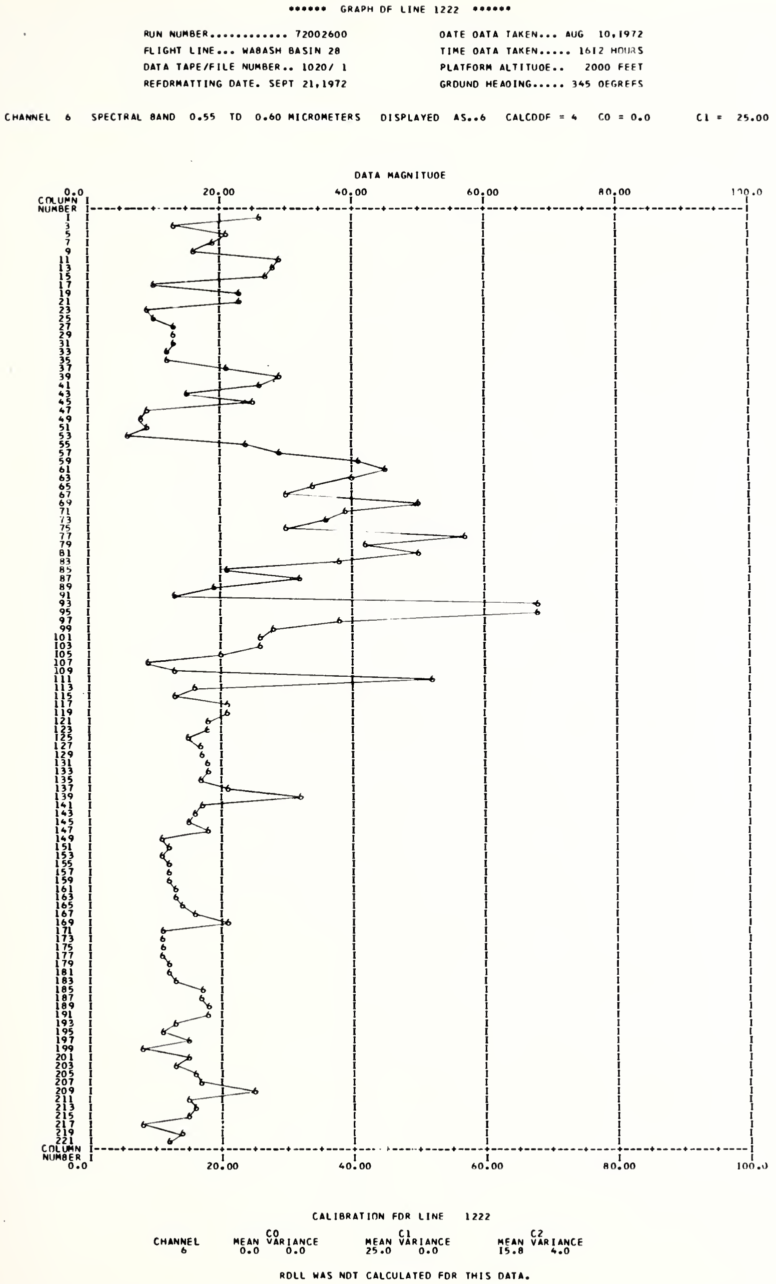
FIGURE 6. *A histogram of the distribution of calibrated apparent surface temperatures (°C) in figure 3. 9.3-11.7um spectral region.*

Figures 5 and 6 are histograms of the distribution of radiant flux intensity of data displayed in figures 2 and 3 respectively. The range of percent reflectance (Fig. 5) is from 2% to over 60% with the majority of the surface reflecting between 10%-20% coincident with the river and vegetated surfaces. The long tail of responses between 20% and 60% is coincident with the majority of man made surfaces in the region. The temperature range (Fig. 6) is between 4°C and 56°C. The low end of the distribution, between 4°C and 20°C, is primarily from the metal roof building. The marked peak at 20°C is the river water and trees. The second peak between 25°C and 35°C is short grass vegetation in the parks and a golf course. The tail from 35°C-56°C are all responses from man made surfaces in the region.

A further view of differences in energy flows across the surface is seen in cross-sectional profiles. Figures 7 and 8 are graphs of line 1222 of the reflectance and emissive data respectively. These graphs represent a typical line of data as viewed by the scanning element of the instrument. Line 1222 is about ⅓ the way down from the top of the alphanumeric displays in figures 4 and 5. Note the low reflectance of the ball park roof in columns 47-53 and the high reflectance of the road surface in columns 91-93 of figure 7. The river channel is in columns 147 to 183. It shows low reflectance with the exception of the waterfall in columns 165-167. Figure 8 is a line graph of the temperature variation across the scene. Note the high temperature of the ball park roof in columns 47-51 and low river temperatures in columns 147-183.

Conclusions

The presented graphics demonstrate the qualitative and quantitative nature of the data. The high resolution of the data provides a unique answer to the problem of investigating synoptic variations in the surface components of the heat or energy budget. The information presented here is a progress report on research which is currently well under way to investigate the impact of urban land use on modifying the energy budget of the earth's surface. Preliminary observations drawn



```
****** GRAPH OF LINE 1222 ******

RUN NUMBER............ 72002600          DATE DATA TAKEN... AUG  10,1972
FLIGHT LINE... WABASH BASIN 28           TIME DATA TAKEN..... 1612 HOURS
DATA TAPE/FILE NUMBER.. 1020/ 1          PLATFORM ALTITUDE..   2000 FEET
REFORMATTING DATE. SEPT 21,1972          GROUND HEADING..... 345 DEGREES

CHANNEL  6   SPECTRAL BAND  0.55  TO  0.60 MICROMETERS   DISPLAYED  AS..6   CALCODE = 4   CO = 0.0      C1 =  25.00
```

```
CALIBRATION FOR LINE   1222

                     CO                 C1                 C2
CHANNEL        MEAN VARIANCE      MEAN VARIANCE      MEAN VARIANCE
   6           0.0     0.0        25.0    0.0        15.8    4.0

ROLL WAS NOT CALCULATED FOR THIS DATA.
```

FIGURE 7. *A graph of simulated percent reflectance in line 1222 of figure 2. 0.55-0.60um spectral region.*

```
                          ******  GRAPH OF LINE 1222  ******

          RUN NUMBER............ 72002600          DATE DATA TAKEN... AUG  10,1972
          FLIGHT LINE... WABASH BASIN 28           TIME DATA TAKEN..... 1612 HOURS
          DATA TAPE/FILE NUMBER.. 1020/ 1          PLATFORM ALTITUDE..   2000 FEET
          REFORMATTING DATE. SEPT 21,1972          GROUND HEADING..... 345 DEGREES

CHANNEL 12   SPECTRAL BAND  9.30  TO 11.70 MICROMETERS   DISPLAYED  AS..C   CALCODE = 4   CO =  1.839   CI =  2.346
```

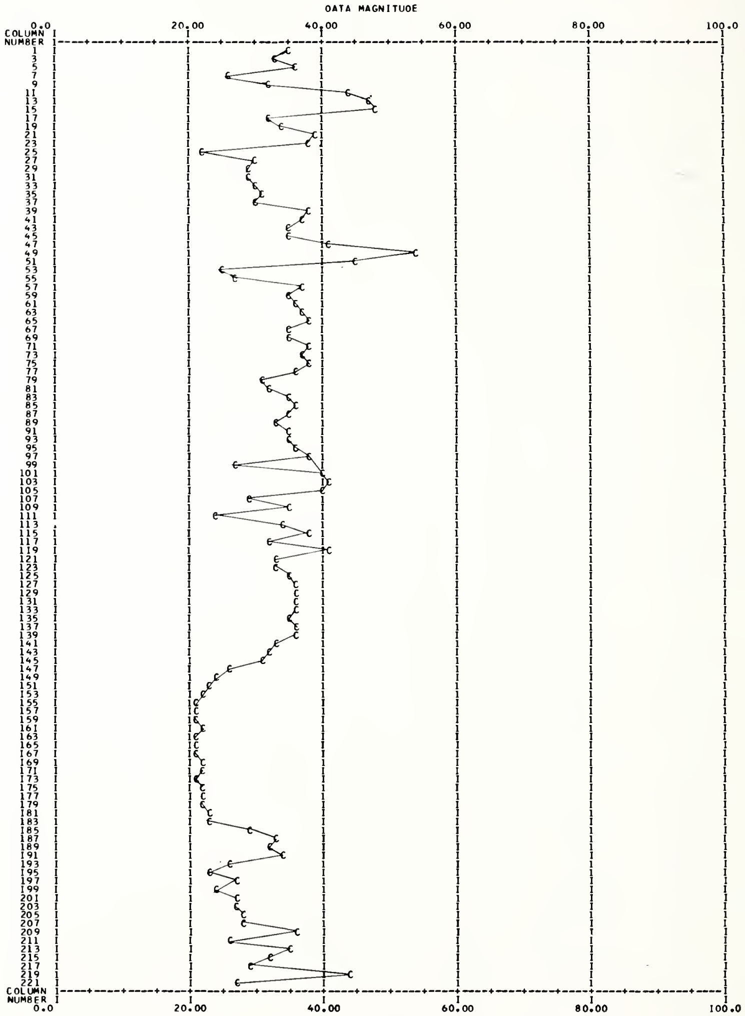


FIGURE 8. *A graph of calibrated apparent surface temperatures (°C) in line 1222 of figure 3. 9.3-11.7um spectral region.*

from August, 1972 data are that urban land use alters surface albedo through increasing the variance of albedo by a factor of 2 to 3 when compared with vegetated surfaces. Man made surfaces on a mid summer afternoon have temperatures which are 2 to 3 times higher than adjacent vegetated areas.

Although a variety of questions related to the temporal variations of the heat budget remain to be answered, the basic methodology by which the detailed synoptic or spatial variations of the energy budget may be identified has been developed by this research conducted at the Indiana State University Remote Sensing Laboratory. The proposed extension of current research is to carry out a coordinated ground and air observation program of a diurnal sequence to investigate the impact of urban land use on the regional climate in detail. It is anticipated that with the LANDSAT C satellite, to be launched in September, 1977, that mesoscale regional studies may also be conducted due to the inclusion of a thermal infrared scanner for the first time in the ERTS-LANDSAT program. Ideally a coordinated research effort relating ground, aircraft and satellite observations will be carried out to make full use of these new multispectral scanners in climatic research.

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The Sedimentation of Morris Pond, Posey County, Indiana

JOHN S. MOORE, Geologist
Soil Conservation Service, USDA
Watershed Planning Staff, No. 1
Paoli, Indiana 47454
and
PAUL F. PEDONE, Geologist
Soil Conservation Service. USDA
Watershed Planning Staff, No. 2
Indianapolis, Indiana 46224

The earthfill dam which impounds 3.82-acre Morris Pond was built in 1949 in an 88-acre watershed in southwestern Indiana. The field survey of the pond indicated its original capacity was 24.94 acre-feet at normal pool elevation, 406.5 feet above sea level. Sedimentation has reduced its capacity 6.53 acre-feet.

The sediment is predominantly silt derived from very erosive, steep upland soils that formed from eolian materials. Fifteen percent of the sediment is seasonally aerated and has a dry density of 90 pounds per cubic foot. Dry density of perennially submerged sediment averages 75 pounds per cubic foot. The trap efficiency of the pond is considered to be 95 percent. Based on these determinations an average of 428 tons, or 4.86 tons per watershed acre, is delivered annually to Morris Pond. The gross erosion rate in the watershed may be two and a half times higher.

General Information

The Soil Conservation Service of the U.S. Department of Agriculture has authorization (Public Law 566) to develop a watershed plan for the Gresham Creek Watershed in Posey County, Indiana (4). The plan may include reservoirs to serve as sediment control structures. The reservoir sites would be located at the base of bluffs forming the margin of the Wabash River Valley near New Harmony, Indiana.

This study was undertaken to determine the average sedimentation rate of an existing pond. The results of the investigation will be used to estimate the sedimentation rates of the planned sediment control structures in the Gresham Creek Watershed. The measurement of accumulated sediment in reservoirs is considered the most reliable source of data for establishing watershed sediment yields (2). Morris Pond was chosen for study because watershed conditions that influence the sediment yield are similar to most sites under consideration.

The pond investigated is owned by Mr. Robert Morris of New Harmony. For the purpose of this study, it is referred to as Morris Pond. The pond is located two miles east of New Harmony, Posey County, Indiana, in sec. 6, T. 5 S, R. 13 W.

The earthfill dam was constructed in 1949 on a minor unnamed tributary of Harmony Creek. The structure has a drop inlet spillway of corrugated metal pipe with a propped outlet, and no emergency spillway. It measures 300 feet long and 16 feet high, and is oriented 15 degrees west of true north. At normal pool elevation, 406.5 feet above sea level, the pond area was 3.82 acres. After 27 years of operation there has been no significant change in water surface area due to sedimentation. The longest axis of the pond is 950 feet, the width averages 160 feet, the maximum observed depth is 13 feet, and the average depth is 4.8 feet.

Character of Watershed

The 88-acre (0.14-square-mile) watershed is situated on deeply dissected bluffs that rise more than 100 feet above a broad, flat terrace of the Wabash River (Figure 1). During the Wisconsinan glaciation, the Wabash River Valley served as a sluiceway for meltwater and became deeply alluviated with glaciofluvial material. On the rolling upland southeast of the bluffs, surface features of the Illinoian till plain have been obscured by a thick loess cap (1).

The bluffs consist mainly of eolian sand and loess over gray Illinoian till. The wind-deposited sand occurs close to the riverward side of the bluffs and thins rapidly toward the south and east away from the Wabash River Valley. Twenty-foot thick exposures of loess are not uncommon, and sections up to 50 feet thick have been measured outside the watershed.

Although no bedrock crops out in the watershed, drilling logs from local wells indicate shales of Pennsylvanian age at depths of about 100 feet.

Soils in the watershed are mainly Sylvan silt loam, Alford silt loam, and Bloomfield loamy fine sand, with minor distributions of Princeton loam. The soil textures clearly reflect the eolian nature of the parent materials. All of the soils are inherently susceptible to severe erosion. Table 1 lists soils data.

Elevations in the watershed range from 406.5 feet above sea level to about 515 feet in the southwest corner of the drainage area. Slopes range from 2 to 50 percent, with more than half the watershed having slopes greater than 18 percent. The streams are either ephemeral or intermittent and are tributary to Harmony Creek.

According to aerial photographs (1953 and 1972 flights), the land use is more than 80 percent unmanaged forest land. The more gently sloping areas near the topographic divides are either pasture and idle-land or cropland.

Precipitation at the New Harmony Station varied from 26.1 to 55.7 inches per year, and averaged 41.8 inches in the period 1955 through 1975 (3). Big Creek near Wadesville, Posey County, is the nearest gaged stream. It has a drainage area of 104 square miles and averages 15.28 inches of runoff per year (8). Based on this information, the mean annual inflow to Morris Pond is about 112 acre-feet of water.

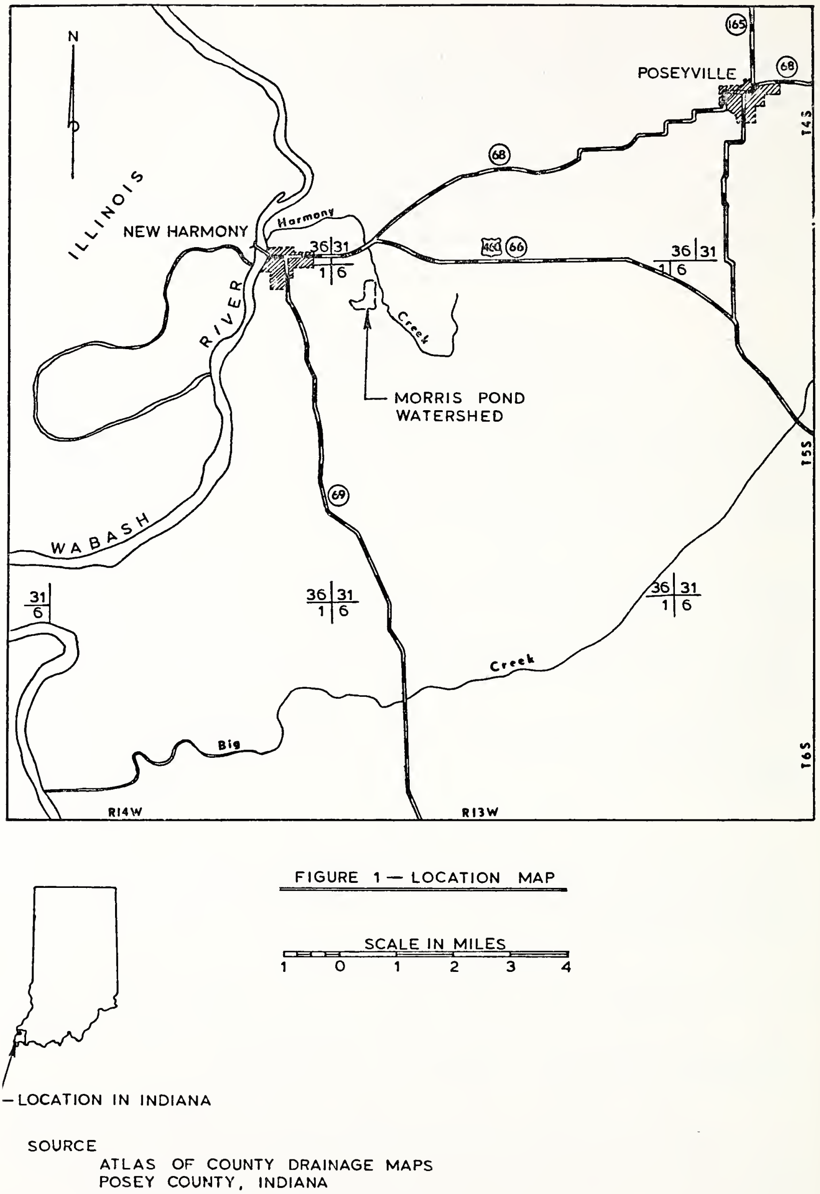
N
ILLINOIS
NEW HARMONY
Harmony
WABASH RIVER
POSEYVILLE
165
68
460
66
69
36 31 1 6
MORRIS POND WATERSHED
Creek
Big Creek
31 6
R14W
R13W
14S
15S
16S
FIGURE 1 — LOCATION MAP
SCALE IN MILES
1 0 1 2 3 4
LOCATION IN INDIANA
SOURCE
ATLAS OF COUNTY DRAINAGE MAPS
POSEY COUNTY, INDIANA

FIGURE 1.

TABLE 1. *Soils Data for Morris Pond Watershed.*

Soil Name	Percentage of Drainage Area	Capability Class	Percent Slope	Soil Loss Tolerance (6) (Tn/Ac-Yr)
Sylvan silt loam	38.4	VIIe	18-50	3
Alford silt loam	28.7	IIe	2-6	3
Alford silt loam	14.9	IIIe	6-12	3
Bloomfield loamy fine sand	14.1	VIe	18-35	5
Princeton loam	2.7	IIIe	6-12	3
Alford silt loam	1.2	IVe	6-12	3

Source: Unpublished soil survey field sheets for Posey County, Indiana, Soil Conservation Service, U.S.D.A.

Theoretically, the pond can recycle its present storage capacity six times per year.

Method of Survey

At the time of the field survey the pond level was at normal pool elevation. A transit and range pole were used to establish a base map with a scale of 80 feet to the inch. Eight ranges were fixed about 100 feet apart and transverse (east-west) to the long axis of the pond. Two other ranges paralleled the dam.

A 10-foot aluminum boat was used as a working platform. A steel tape was used to measure the depth to the sediment-water interface at each station. A soil auger with necessary extensions was pressed into the sediment to the original bottom. The original (1949) bottom was distinguished by an abrupt increase in density whereupon no further penetration was possible without turning the auger. The east-west ranges were probed at 20-foot intervals and the north-south ranges at 40-foot intervals. A total of 65 stations were probed (Figure 2).

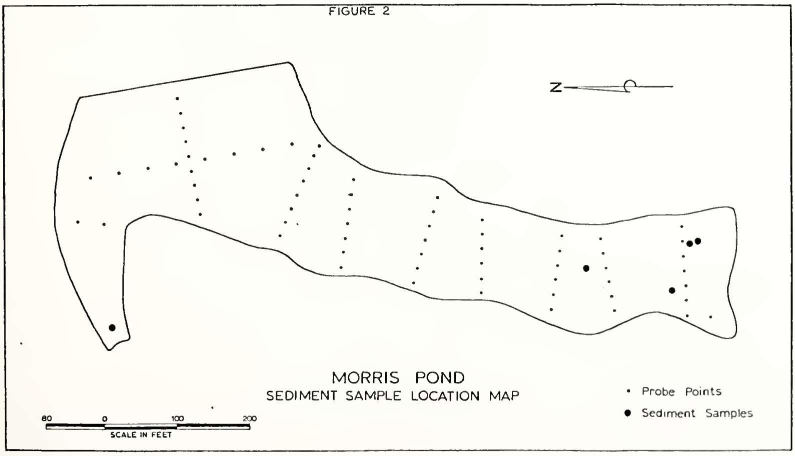

FIGURE 2.

Five sediment samples were taken to determine dry density, water content, grain size distribution, and organic content. A piston sampler with a core barrel 1.5 inches by 36 inches was used to collect the samples. Samples were taken from the seasonally aerated delta and the perennially submerged area in the south side of the pond, and in the northwest arm (Figure 2).

Storage Capacity

The depths to present bottom and to original bottom were plotted and contoured on a 2-foot interval (Figures 3 and 4). Each contour line was planimetered for area and its value was plotted on stage-storage and

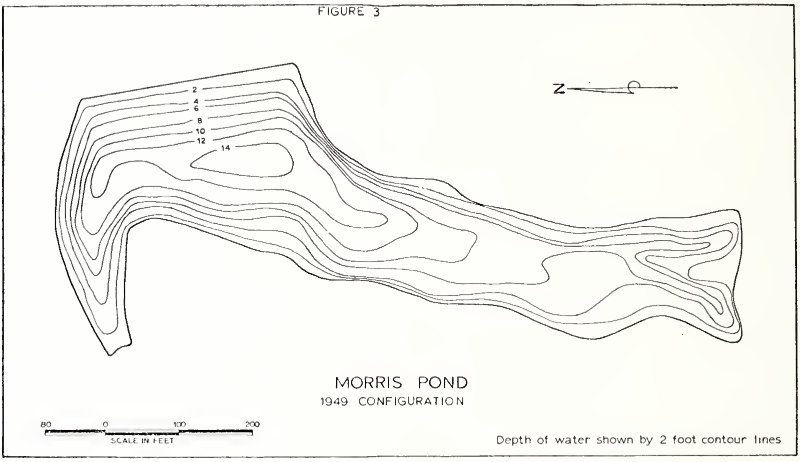
FIGURE 3
2
4
6
8
10
12
14
Z
MORRIS POND
1949 CONFIGURATION
80
0
100
200
SCALE IN FEET

Depth of water shown by 2 foot contour lines

FIGURE 3.

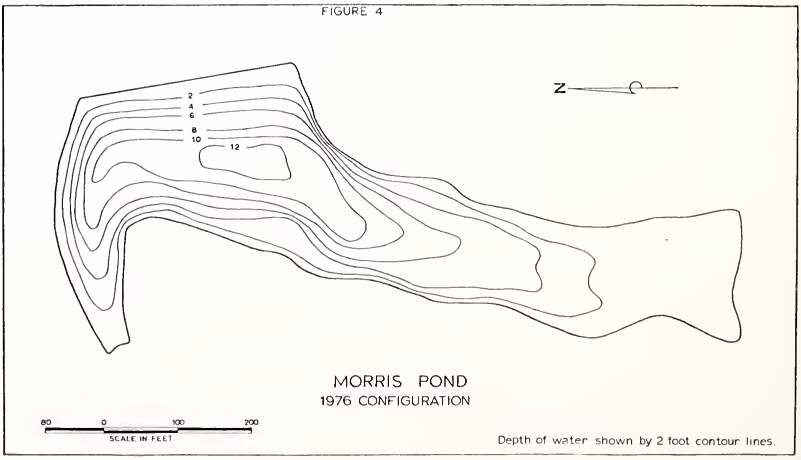
FIGURE 4
2
4
6
8
10
12
Z
MORRIS POND
1976 CONFIGURATION
80
0
100
200
SCALE IN FEET

Depth of water shown by 2 foot contour lines.

FIGURE 4.

stage-area curves for both the 1949 and 1976 configurations. The original (1949) pond volume at normal pool level was 24.94 acre-feet. The present pond capacity is 18.41 acre-feet. The difference of 6.53 acre-feet represents the sediment volume.

Sediment Deposits

The isopachous map (Figure 5) shows the distribution and thickness of sediment in 2-foot contour intervals. Sedimentation is greatest in the south end of the pond where two tributary channels have filled with deltaic deposits up to six feet in thickness. Two to four feet of sediment have accumulated along the central axis of the pond where the water is deepest, and in the northwest arm. Directly behind the dam the contours encircle a depression which probably represents the borrow area for the dam construction materials. Most of the nearshore sediments are less than two feet thick. The sediment of Morris Pond averages 1.71 feet in thickness.

FIGURE 5

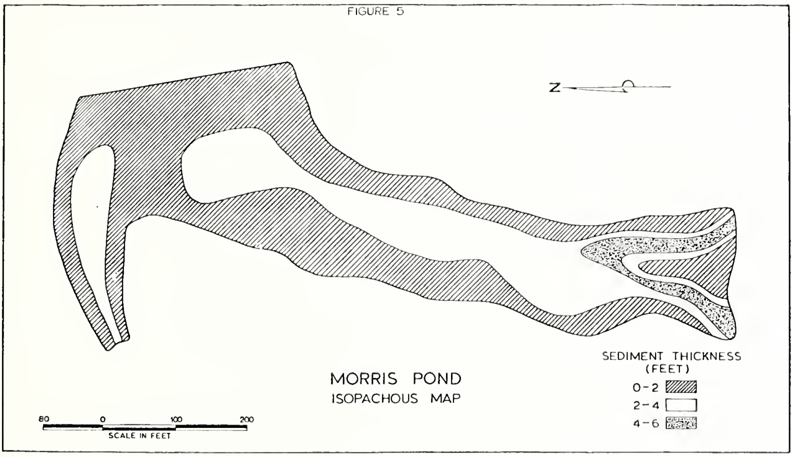

Figure 5.

Approximately 15 percent (0.98 acre-foot) of the pond's sediment is seasonally aerated and occurs mainly in the south end of the pond. The aerated sediment dry density averages about 90 pounds per cubic foot (1.44 specific gravity), and the submerged sediment about 75 pounds per cubic foot (1.20 specific gravity). The water content averages 25 percent and 30 percent, respectively.

The texture of the sediment in the south delta is predominantly silt or silt loam. Clay content ranged from 9 to 10 percent, silt 76 to 91 percent, sand 2 to 15 percent, and organic matter 4.9 to 5.7 percent. In the northwest delta the sediment texture is sandy loam, with 6 percent clay, 42 percent silt, 52 percent fine sand, and 6.0 percent organic material. Grain size was determined by mechanical analysis. Organic matter content was measured by loss upon ignition.

Sources and Rates of Sedimentation

Most of the sediment in Morris Pond appears to be derived from the two southern sub-watersheds that drain 77 percent of the total drainage area. The soils are mainly erosion-prone Sylvan and Alford silt loams with slopes up to 50 percent.

The northwest delta is the only area where sand is accumulating in appreciable quantity. Drainage to this part of the pond is mainly from an area of Bloomfield loamy fine sand.

The sedimentation rate over the 27-year depositional history of the pond averaged 407 tons per year. Based on determinations of sediment mean grain size and the ratio of pond capacity to average annual inflow, the trap efficiency is considered to be approximately 95 percent (7). Therefore, an average of 428 tons, or 4.86 tons per watershed acre, is delivered annually to the pond.

If the 0.14-square mile drainage area is considered to deliver 40 percent of all eroded material (5), then the gross erosion rate would average 12.15 tons per acre per year. Thus, the gross erosion rate may be 2.5 times higher than the delivery rate. Table 1 shows that the soil loss tolerances of the watershed soils range from 3 to 5 tons per acre per year (6). Although most of the drainage area is in forest land, grazing and cropping on the steep uplands have, over the years, greatly contributed to the high erosion rates.

Summary

The 3.82-acre Morris Pond was built in 1949 in an 88-acre watershed. This watershed is located on the bluffs above the Wabash River Valley near New Harmony, Indiana. A survey of the pond indicated that the original storage capacity at normal pool level was 24.94 acre-feet. In April, 1976, the capacity was 18.41 acre-feet. Sedimentation has reduced the original volume by 6.53 acre-feet.

Sediment is up to six feet thick in the south delta where the junction of two subaqueous tributary channels has been buried by progradation. Sediment has accumulated in the thalweg of the pond in thicknesses up to four feet. Sediment near the shoreline is generally less than two feet thick.

The sediment is predominantly silt with 5 to 6 percent organic matter. Eighty-five percent of the sediment is submerged with a dry density of about 75 pounds per cubic foot. Aerated sediment averages 90 pounds per cubic foot. The sedimentation rate has averaged 407 tons per year. Assuming the trap efficiency of the pond is 95 percent, an average of 428 tons, or 4.86 tons per watershed acre, is delivered annually to the pond. The gross erosion rate may be two and a half times higher.

The results of this investigation will be used to estimate the sedimentation rates behind sediment control structures and to recommend conservation land treatment measures in the Gresham Creek Watershed as planned by the Soil Conservation Service.

Acknowledgments

The authors thank Robert and David Morris for permission to conduct the field investigations on April 5-8, 1976. A. Keith Gilmore, planning engineer, SCS Watershed Planning Staff, Paoli, Indiana, assisted with the surveying. Donald Weaver, District Conservationist, Posey County made necessary arrangements.

Other members of the Watershed Planning Staff deserving recognition are Vincent Crowder, engineering technician, who drafted the illustrations, and Evelyn Gregory, secretary, who typed the manuscript.

Sediment grain size and organic content analyses were conducted by the Soil Mechanics Laboratory, Midwest Technical Service Center, Soil Conservation Service, Lincoln, Nebraska.

This report is published with the permission of the Indiana State Conservationist, Soil Conservation Service. USDA.

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HISTORY OF SCIENCE

Chairman: William R. Eberly
Manchester College, Manchester, IN 46962

Chairman-Elect: Gertrude L. Ward
Earlham College, Richmond, IN 47374

ABSTRACTS

Rafinesque Revisited. Gertrude L. Ward, Joseph Moore Museum, Earlham College, Richmond, Indiana 47374.——The life of Constantine S. Rafinesque (1783-1840) was reviewed with comments on his employment as a teacher for the family of Edward Livingston at Germantown, N. Y., his walking tour to Indiana and Kentucky in 1818, and his meeting with John J. Audubon. Several genera, species and subspecies of plants that he described were illustrated. His comments on speciation in plants, predating Darwin and Wallace's, were included.

Further Studies in the History of the Phosphate Detergent Ban. William R. Eberly, Manchester College, North Manchester, Indiana 46962.——In 1971 the Soap and Detergent Association and/or its affiliated member companies filed suits challenging the constitutionality of bans on phosphates in detergents enacted in Indiana, Dade County (Fla.), Erie County (N.Y.) and Chicago (Ill.). In the first 3 cases, the courts found the laws not unconstitutional. In the Chicago case, the regulation was ruled unconstitutional. That case was appealed and on January 15, 1975, the U.S. Court of Appeals reversed the decision of the lower court. When the Supreme Court refused to hear an appeal by the Soap and Detergent Association, the Appeals court decision became final. All court action has now found such laws restricting phosphorus in detergents to be legal and appropriate action.

Indiana was the first state to ban phosphates in detergents on January 1, 1973, with New York following in July, 1973. In 1975 the Minnesota Pollution Control Agency held hearings on a proposed regulation banning phosphorus detergents in Minnesota. The ruling (WPC 37) was adopted on April 27, 1976 and becomes effective January 1, 1977. The Senate Natural Resources Committee of the Vermont State Legislature held hearings on a bill to restrict phosphates in Vermont (S.128). The bill was narrowly defeated in the 1976 legislative session. The bill will be considered again by the 1977 legislature. The Michigan Department of Natural Resources held hearings on a regulation to ban the sale of phosphate detergents in Michigan. They are scheduled to act on this proposal in December, 1976.

In a report issued in December, 1975, the International Joint Commission (IJC) analyzed the phosphorus output from 12 municipal sewage treatment plants which collectively contributed more than 80% of all the municipal sewage flowing into Lake Erie. Most of the plants had supplemental phosphorus removal operations. Only Fort Wayne

(Indiana) and London (Ontario) had achieved the goal of 1 ppm P in the sewage effluent in 1974. The report strongly suggests that phosphorus removal treatment by itself is not adequate to reach the desired concentration of P in the effluent and that restrictions of P in detergents is necessary also. In their annual report (July, 1976) the IJC repeated their recommendation that "all the Great Lakes states that have not already done so should seriously consider the imposition of phosphorus limitations in detergents marketed in the Great Lakes Basin."

In August, 1976, for the first time the United States Environmental Protection Agency adopted a position urging all the Great Lakes states to restrict the use of phosphorus in detergents. An official position paper is in preparation by the EPA.

Was Theodore Roosevelt the Last to See Wild Passenger Pigeons?

ALTON A. LINDSEY
Department of Biological Sciences
Purdue University, West Lafayette, Indiana 47907

The State Legislature of Ohio declared in 1857, "The passenger pigeon needs no protection. Wonderfully prolific, . . . no ordinary destruction can lessen them from the myriads that are yearly produced." The last individual of this species, once the world's most abundant bird, died in that same state. A female named Martha, the last of a line started with four pairs captured near Petosky, Michigan, in 1878 (Pers. Comm. E.J. Maruska, 1976), died at age 29 in the Cincinnati zoo on September 1, 1914. The mounted skin is now in the U.S. National Museum. But of far more interest is what happened to the species in Nature.

The most informative contemporary account for the Midwest after Audubon's time was published by Chief Simon Pokagon in 1895. His article was reprinted in Mershon's supposedly definitive 1907 book (8) on the passenger pigeon and its extinction in the wild.

Of the latest four records Mershon cited for Indiana, three were from English Lake, a great spread of the Kankakee River now perpetuated only in the name of a village. One male pigeon was shot there in 1887, and the specimen preserved by Ruthven Deane. The latter shot a young female on Yellow River, Stark County, in September, 1888. In both cases the birds were alone. John Hazen shot eight individuals from a small flock at English Lake in 1887. The last Indiana record was in 1893, when C. B. Brown of Chicago collected a nest and two eggs, very close to the Hazen site at English Lake. He secured both parent birds, but preserved only the eggs. Governor Chase S. Osborn saw six birds in Michigan in 1890, and one in 1897.

Observations at Pine Knot, Virginia

From 1905 for the rest of his life, Theodore and Edith Roosevelt had a week-end cottage called "Pine Knot," now-forgotten although still standing, on ninety acres of woods near Charlottesville, Virginia. This simple hideaway (Fig. 1) was the locale of most of his natural history observing (except that done with Muir at Yosemite and with Burroughs at Yellowstone) during his 7.5 years in the White House. In late May of 1907 the president wrote the following letter to his friend C. Hart Merriam, director of the U.S. Biological Survey. (The paragraphs are lettered for ease of subsequent reference.)

(a) On May 18th near Keene, Albemarle County, Virginia, I saw a flock of a dozen passenger pigeons. I have not seen any for twenty-five years and never dreamed I should see any again; but I could not have been mistaken (tho I did not kill any for I did not have a gun, and in any event nothing could have persuaded me to shoot them.)

I saw them flying to and fro a couple of times and then they all lit in a tall dead pine by an old field. There were mourning doves in the field for me to compare them with, and I do not see how I could have been mistaken.

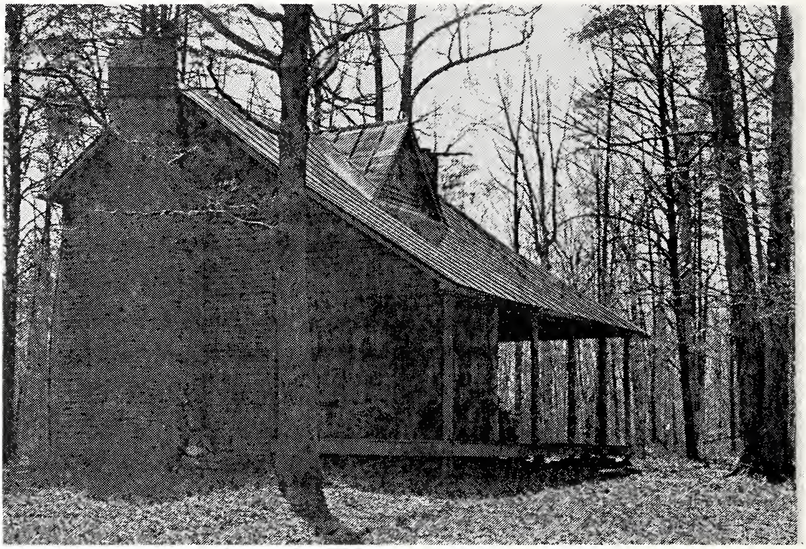

FIGURE 1. *Pine Knot in April, 1976; basically unchanged since 1905. "When I was president, we owned a little house in western Virginia; a delightful house, to us at least, although only a shell of rough boards." (11). The cottage and fifteen acres with a spring were given to Mrs. Roosevelt by family friends, and TR had two chimneys and fireplaces added. Later, Mrs. Roosevelt obtained 75 additional acres and owned it all until 1941. It is now privately owned, unoccupied, and unmarked.*

(b) In replying to a similar letter from TR, John Burroughs (2) wrote that he had been checking for several years on reports of the species, stressed how rare the bird had become, if indeed it still existed in the wild, and added, "I hope you are sure about those pigeons."

(c) Roosevelt wrote Burroughs on June 2 (9), "Dear Oom John: I have written down to see if I can get information about those passenger pigeons. It doesn't seem to me possible that I was mistaken. Nevertheless, I have had one or two curious experiences of the fallibility of human vision." He went on to tell an incident when he and a cowboy had mistaken the color of prairie dogs because of "the peculiar angle at which the sunlight struck them." He invited Burroughs to be their guest at Pine Knot (1), holding out some possibility of seeing the pigeons; meanwhile, he would follow up a remark that the colored foreman at a neighbor's farm had made (11) about seeing "wild carrier pigeons." That neighbor and friend, Wilmer, questioned Dick McDaniel and wrote Roosevelt what the latter considered confirmation, since TR believed that Dick's practical knowledge of birds was absolutely trustworthy.

(d) On May 12th last Dick saw a flock of about thirty wild pigeons, followed at a short distance by about half as many, flying in a circle very rapidly, between the Plain Dealing house and the woods, where they disappeared. They had pointed tails and resembled somewhat large doves—the breasts and sides rather a brownish red. He had seen them before, but many years ago. I think it is unquestionably the passenger pigeon—*Ectopistes migratoria*—described on page 25 of the 5th volume of Audubon. I remember the pigeon roosts as he describes them, on a smaller scale. . . .

In his lead article in the next October's *Scribners*, in which TR discussed the bird life at Pine Knot in some detail, the first printed account of his pigeon sighting is worded as follows.

(e) On May 18th, 1907, I saw a small party of a dozen or so passenger pigeons, birds I had not seen for a quarter of a century and never expected to see again. I saw them two or three times flying hither and thither with great rapidity, and once they perched in a tall dead pine on the edge of an old field. They were unmistakable; yet the sight was so unexpected that I almost doubted my eyes, and I welcomed a bit of corroborative evidence coming from Dick, the colored foreman at Plain Dealing. Dick is a frequent companion of mine in rambles around the country, and he is an unusually close and accurate observer of birds, and of wild things generally. Dick had mentioned to me having seen some "wild carrier pigeons," as he called them; and, thinking over this remark of his, after I had returned to Washington, I began to wonder whether he too might not have seen passenger pigeons.

(f) John Burroughs was a guest at Pine Knot (1) for four days in late May, 1907. The two naturalists on excursions together identified 75 species of birds, Burroughs pointing out two that were new to TR, and the latter teaching John O'Birds two species new to him and showing him another that the old essayist had not seen for thirty years (3). Burroughs wrote after TR's death that the president had known the warblers in the trees overhead that spring as well as he did himself. No pigeons were seen this time, but the two men questioned Dick McDaniel face to face about all aspects of his sighting. In Burroughs 1921 book, he wrote (3), "His description agreed with Roosevelt's, and he had seen wild pigeons in his youth; still I had my doubts." But Burroughs (2) had reported very differently in print on July 13, 1907—"He [TR] would have the matter looked into by a friend at Pine Knot upon whom he could depend. He did so, and convinced himself *and me also* (emphasis added) that he had really seen wild pigeons.

(g) Also, in his 1921 chapter on the Pine Knot visit, Burroughs (3) wrote the following.

In the course of that walk he showed me a place where he had seen what he had thought at the time to be a flock of wild pigeons. He described how they flew, the swoop of their circling movements, and the tree where they alighted. I was skeptical, for *it had long been thought that wild pigeons were extinct* (emphasis added), but that thought had not impressed itself upon his mind.

Behavioral Evidence for the Identification

The only other birds with pointed tails that a bird student of Roosevelt's high capability might conceivably have confused with passenger pigeons are mourning (Carolina) doves. McDaniel stressed the size element; TR implied it by his comparison with nearby doves since size is the most obvious difference. Eaton (5) wrote, "The mourning dove is much smaller than the wild pigeon." He gave lengths as 11-13″ *versus* 15-17.5″ and wingspread, the distinction most apparent in flight, as 17-19″ for the dove and 23-25.5 for the pigeon. The latter has a much longer tail.

Roberts (10) wrote, "The whistling of the wings of the dove in flight, a sound never heard from the wild pigeons, is a safe and easily noted distinction." Neither observer reported this, even though a person close enough to have seen the red breasts would probably have heard this sound had it been made. Sound or song was what most interested Roosevelt about birds, as stressed in his writings; he was considered an expert on bird sounds, and if he had heard the distinctive whistling he would not have been likely to have believed the birds were passenger pigeons.

Almost as strong a point of difference was flocking behavior; the passenger pigeon was probably the most gregarious of all birds. Until it reached its last extremity, this species was always seen in flocks. It fed, roosted, wintered, migrated, mated, nested and stayed in flocks. In contrast, mourning doves are primarily oriented to the pair-bond. Reports of flocks are unusual, and they are for fall and winter. Even in an abnormally cool year, doves are paired and nesting in Virginia long before mid-May. The only imaginable flock of mourning doves on May 18 might be young of the year, but they lack the red breasts, and would be unlikely in such numbers as seen by McDaniel, about forty-five. It is also very questionable that they would be such skillful fliers by mid-May as to go as rapidly as reported.

Forbush (6) wrote of passenger pigeons, "In searching for food in a country where it was plentiful, the birds flew low, and, upon reaching good feeding ground, swung in large circles while examining the place." Circling or swooping, flying back and forth, was the most striking behavioral feature in both men's descriptions. They were in the open, their views unobstructed by trees. On my visit to Pine Knot (finally located by a search of early deed records at the County seat) in April of 1976, I found woods completely surrounds the Roosevelt's cottage, now unoccupied but in fair condition. But a photograph taken by TR from the front porch in 1907 (11) enables us to see far off over sloping terrain rather recently cut over and being invaded by very scattered young pines. Perhaps this open ground was the "field" he referred to.

Reports and Records in and near 1907

Mershon's book (8), in press in 1907, reported that a passenger pigeon was shot in 1900, in Wisconsin. A later authority on this species records was J. H. Fleming, a vice-president of the American Ornithologists Union. The last collected specimen for which he determined the date was authentic was a single bird shot in August of 1906 in Fairfield County, Connecticut (14) and now a mounted specimen in the Museum of History, Science and Art at Los Angeles.

During roughly the last twenty years of the bird's wild existence, ornithologists discounted the plethora of sightings claimed by untrained persons and unsubstantiated by a specimen, because so many laymen's reports were obviously based on mourning doves, or on distant flocks of other birds, e.g., curlews. In New York state (5), two claims of flocks were made in 1904, and two in 1905. Another 1905 claim, for a sighting of six birds, was from Michigan (7). John Burroughs, who never made a museum skin and was a literary naturalist rather than a scientific one, started about 1905 to check some of the popular announcements in newspapers (2, 5). He reported (5) that someone claimed a large flock at Prattsburgh, New York, in mid-April, 1906, and one a mile long at Kingston, N. Y., on May 15, 1906. Finally, Burroughs interviewed a farmer in Sullivan County, N. Y., who claimed to have seen a flock of 1,000 pigeons on May 23, 1907, or five days after Roosevelt's sighting. Burroughs indicated in *Forest and Stream* and in letters (8) that he was convinced of the validity of these three sightings.

Unreliability of Burroughs Last Account

John Burroughs essay on the Pine Knot visit (3) was published after his death at age 84, or 14 years after the event. "Wild pigeons" were clearly extinct by that time, and Burroughs' tone had completely changed from that in the 1907 letters and publications (f). This seems to reflect either carelessness, senility, or disingenuousness. How could he, in 1907, have "long thought the bird extinct" while he himself was still publishing (2, 8) and crediting reports of purported flocks by laymen in 1906 and 1907?

Burroughs was clearly wrong in two incidental statements in his 1921 chapter (3), which suggests faulty memory—the events of the White House dinner the night before the Pine Knot visit (they happened in 1903 instead), and his stating that the party left the train at Charlottesville, instead of North Garden.

It appears that a more important 1921 comment was likewise untrue—"Subsequently Roosevelt wrote me that he had come to the conclusion that they had been mistaken about their being pigeons." The closest TR came to retracting his pigeon report was his letter (c) saying, in effect, that while he was still certain in his own mind, of course he did not think himself infallible. This letter was written *before* receiving the corroborating letter from Wilmer (d). In response to Burroughs stringent cautionings, TR volunteered that certain lighting conditions make perception of colors difficult. But, so far as he wrote, his own identification was not based on color, but on size, the pointed tails, the circling behavior, speed of flight, and best, on direct comparison with mourning doves.

That Burroughs was wrong in claiming that TR had changed his mind (3) is clear from TR's having published his passenger pigeon sighting in Scribners Magazine in October, 1907, and having allowed this claim to be reprinted in the various editions of his book *Outdoor Pastimes of an American Hunter,* of which the last edition came out in 1926 (12).

Burroughs' tardiness in printing the essay was not for lack of encouragement from Roosevelt, for he wrote (3), ". . . in fact, for years after the visit, whenever we would meet, almost the first thing he would say was, 'Have you written up our Pine Knot trip yet, Oom John?' And his disappointment at my failure to do so was always unmistakable." The evidence shows that TR held to his original statements, of which the weakest expression was "I do not see how I could have been mistaken." In contrast, Burroughs' writings (f,g) about Roosevelt's sighting were clearly inconsistent.

Credibility of Observer Roosevelt

At age 13 or younger, Theodore Roosevelt (13) took lessons in taxidermy from an old Mr. Bell who had traveled as Audubon's assistant, and the boy began a collection of bird skins that Cutright (4) judged to be the best of any young naturalist in North America. At age 14, TR went on a 1,200 mile houseboat trip on the Nile, and reported (13) that intensive bird collecting was the most interesting thing he did there and in Palestine. A couple of hundred of his boyhood museum skins are still in museums; 46 were given to his friend David Starr Jordan for Indiana University. TR's phenominal memory enabled him to name the Nile birds on sight in the field 37 years later, when he spent a year in Africa collecting thousands of bird and big game specimens for the two great eastern museums.

Young Roosevelt majored in biology at Harvard (13), fully intending to go into a career as a field naturalist. His first printed work was a study of Adirondacks bird life, done during undergraduate days with a fellow student, Minot. The first letter he wrote in his life, and the last one, dealt with birds. C. Hart Merriam stated in Science in 1932 that TR was ". . . a writer of the best accounts we have ever had of the habits of our larger mammals." He wrote the most reasonable early account on the theory of protective resemblance. With a Smithsonian naturalist, he authored the then-definitive book on African mammals, writing the life history and behavioral parts himself. He was the first to suggest the idea of naturalists living with their subjects for long periods, a method that has proved so fruitful in Africa recently, beginning with Shaller's work with the mountain gorilla. Theodore Roosevelt was a naturalist from first to last. Rather than being a dilettante, he was an amateur of high professional caliber as a field naturalist. As a literary naturalist however, the success of his western nature and hunting books made him a part-time professional.

After birding with TR at the White House Grounds, Pine Knot, Yellowstone Park, and Sagamore Hill, Burroughs (2) wrote:

> I refer to his keenness and enthusiasm as a student of animal life, and his extraordinary powers of observation. He sees quickly and surely, not less so with the corporeal eye than with the mental. . . . The chief qualification of a born observer is an alert, sensitive, objective type of

mind and this he has in preeminent degree. . . . His mind moves with wonderful celerity, and yet as an observer he is very cautious, jumps to no hasty conclusions.

Roosevelt's wide experience in hunting and collecting brought him a reputation as one of the best marksmen of his day. His first wild turkey was brought down cleanly from the air, a forty-yards side-shot, on the third day of a strenuous hunt at Pine Knot with Dick McDaniel. No one is as well qualified as a crack wing-shot to estimate the rapidity of bird flight. Both TR and Dick McDaniel reported the wild pigeons were flying rapidly.

Ornithologists at the American Museum of Natural History, because they were familiar with his expertise on birds and since he had seen mourning doves for comparison, accepted his passenger pigeon sighting as authentic.

Conclusions

Roosevelt did not claim to have seen the last wild passenger pigeons; he was too busy in 1907 to be following what others were doing on the question, and did not push Burroughs or others to accept his sighting. He wrote (9) that he could not afford to get into a natural history controversy at that time. He meant *another* controversy, for he was under press attack for allowing the presidency to become embroiled in the "Nature faker" controversy. Still, he stuck to his story in every published reference to it afterward.

"Was Theodore Roosevelt the last *person* to see wild passenger pigeons?" The question in that form can never be answered with assurance. He may have been, but we will never know whether any farmers or hunters saw some after his sighting without getting it into print.

What I have investigated was whether TR was the last trained, qualified naturalist to see a flock of wild passenger pigeons. This is an answerable question because naturalists report their observations. The evidence strongly indicates that he identified his flock correctly. Granting that, a president of the United States, on his own property, was definitely the last naturalist to see the species in nature. Roosevelt's distaste for going back for his shotgun and killing any of them should not deprive him of his most dramatic bird record.

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A History of the Biological Survey Committee of The Indiana Academy of Science

1891-1976

Part I: 1891-1935[1]

Introduction

This history of the Biological Survey Committee was prepared by the members of the Committee, 1976, in response to a request made by John S. Patton, President of the Academy, 1975-76. At the annual meeting of the Academy, October 31, 1975, Butler University, he proposed that, "an office entitled Historian-Archivist be established in the Indiana Academy of Science in order that we may have a formal method of assembling archival material and compiling historic information about the Academy and its activities." The Academy accepted President Patton's proposal, and information relative to it was received by Jack R. Munsee, Chairman of the Biological Survey Committee, in a form letter from Patton dated December 30, 1975. The request was for archival items relative to the history of the Committee; such items to be forwarded to the John Shepard Memorial Library at Indianapolis.

Because of the paucity of records of past activities, the attempt has been made to assemble a history of the Committee using information obtained chiefly from the Proceedings of the Academy. (The first meeting of the Academy was in 1885; however, the first volume of the Proceedings was not published until 1891. Therefore, the titles of all papers prior to 1891 were included in Volume 1.) Each of the nine members of the present committee was asked to prepare a document based on information concerning the Committee as given in the Proceedings. Each document covered a nine-year segment as represented by the dates of publication of the Proceedings. The chairman prepared the document covering the last five years of the Committee's history.

The members of the Committee and the years reported by each were: Theodore J. Crovello, University of Notre Dame (1891-1899); James R. Gammon, DePauw University (1900-1908); Morris Levy, Purdue University (1909-1917); Gayton C. Marks, Valparaiso University (1918-1926); Victor Riemenschneider, Indiana University, South Bend (1936-1944); David S. Woodruff, Purdue University (1945-1953); Willard F. Yates, Jr., Butler University (1954-1962); Frank N. Young, Jr., Indiana University (1963-1971); and Jack R. Munsee, Chairman, Indiana State University (1972-1976). The period 1927-1935 was reported by Irene Horner, student at Indiana State University, since J. W. Reising, committee member, was unable to prepare this segment of the history.

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[1] Published in two Parts. Part II: Volume 87, Proceedings of the Indiana Academy of Science for 1977.

Report prepared by the Biological Survey Committee under the direction of Jack R. Munsee.

A committee was formed early in the history of the Academy, whose functions have apparently always dealt with aspects of the flora and the fauna of Indiana. Reports prepared by the Committee appear in most issues of the Proceedings, however, no reports were forthcoming in some years. Occasionally, the need for such a committee has been questioned by members of the Academy; nevertheless, it has survived as evidenced by the account of its history which follows. Among the names of many who have served on the Committee will be recognized those of well-known Indiana biologists whose works laid the foundation for understanding and appreciating the wealth of diversity of living things to be found in Indiana.

1891-1899 (T. J. Crovello)[1]

(Major dates, e.g., 1891, refer to information obtained from the Proceedings with *that* date on its cover, although it might not have been published until a subsequent year.)

1891

The closest committee to the Biological Survey Committee was that on the Legislation for the Restriction of Weeds. It consisted of J. C. Arthur, J. M. Coulter, and W. H. Evans and was in effect in 1890-91. Also related to the Biological Survey Committee was the Committee on Legislation for the Protection of Native Birds (1887-91). It consisted of A. W. Butler, D. S. Jordan, and B. W. Evermann.

1892

In the published summary of the spring meeting of the Academy held at Terre Haute, May 12-19, 189*3* [sic], is included a report from "the Committee on State Biological Survey," by its only member, L. M. Underwood. He was charged "to appoint two other members to serve on the committee with him and to present plans at this meeting for carrying on the work." Later in the meeting, three "directors" were approved: L. M. Underwood, C. M. Eigenmann, and V. F. Marsters.

Of interest is the listing of Curators (of the Academy?) along with the Academy's officers. The Curators were:

Botany	John M. Coulter
Icthyology	Carl H. Eigenmann
Ornithology	Amos W. Butler
Herpetology	O. P. Hay
Entomology	F. M. Webster
Mammalogy	E. R. Quick

While they may have been Curators of the Academy, they were not all located in one city. For example, Coulter's address is given as Lake Forest, Illinois. [Also, the first sentence on page 14 of the 1893 Proceedings indicates certain collections were to serve as official depositories.]

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[1] Although the entire substance of each committee member's report is used, where necessary, minimum editing was done in order to effect cohesion among the separate reports.

Papers read at the Winter Meeting at Indianapolis (Dec. 28-29, 1892) include one given (title only) by L. M. Underwood (page 48), "A State Biological Survey—A Suggestion for Our Spring Meeting."

1893

Almost 200 pages of the approximately 275 pages of the 1893 Proceedings (published in August, 1894) are devoted to the Biological Survey. In addition, the list of Committees for 1893-94 record two relevant entries:

1. Biological Survey (BSC): L. M. Underwood, A. W. Butler, J. M. Coulter.
2. Directors of Biological Survey: L. M. Underwood, C. H. Eigenmann, V. F. Marsters.

Nowhere is it clearly stated what the different functions of these two might be. However, on page 13, Lucien M. Underwood, Director of the State Biological Survey, does provide this glimpse of purpose of the two:

"The Indiana Academy of Science at its spring meeting originated the State Biological Survey by the appointment of three directors who were instructed to organize the survey and prepare for the winter meeting a Bibliography that would show the present status of the knowledge of the state flora and fauna, recording in accessible form what had been already written concerning them. It was further thought desirable to outline certain features of new work that could be reasonably attempted during the season of 1893. In order to make known the purposes of the survey the following general statement was published and somewhat widely distributed through the state in July last:"

Biological Survey of Indiana

Circular No. 1

"At the last meeting of the Indiana Academy of Science, at Terre Haute, a Biological Survey was established for the State of Indiana, and the undersigned were appointed Directors to organize the survey and outline the preliminary work ordered by the Academy."

"It is the purpose of the survey: (1) To ascertain what has already been accomplished in the direction of making known the character and extent of the life of the state, and to this end to prepare a complete bibliography of materials bearing on the botany, zoology, and palaeontology of Indiana, to be published by the Academy. (2) To associate the various workers throughout the state, and so correlate their labors that all will work together towards a definite end, and ultimately accomplish the main purpose of the survey, namely, the making known of the entire fauna and flora of Indiana, its extent, its distribution, its biological relations, and its economic importance. (3) To stimulate the teachers of biology throughout the state to encourage in their pupils the accumulation of material, which shall make known the local extent and distribution of life-forms, and thus contribute facts that will be useful in the survey and at the same time develop acute observers for continuing the study of the natural resources of the state. It is thus intended that the colleges and secondary schools will form with the survey a mutually helpful relation. (4) Ultimately to secure for the Academy a collection that will illustrate the biology of the state. Until such collection can be otherwise provided for, the Academy will designate certain public or private collections where accumulated material may be deposited temporarily. Material sent to the directors will be thus held for the future disposition of the Academy."

"It is earnestly requested that all persons interested in any department of biological work will place themselves in relation with the directors of the survey at once, in order that their work may be made to contribute the most effectively to the public good, and in order that the directors may know on whom they may depend for gaining information from various portions of the state. All contributions from persons interested will be properly credited in the reports of the survey. Correspondence is solicited with the director of the particular branch in which any one is interested, and such directions in regard to collecting and sending material will be given on application. By the assistance of the Smithsonian Institution, the directors are able to send printed directions for collecting to such as apply for them. (In ordering these it will be necessary to specify in what particular branch information is desired.)"

LUCIEN M. UNDERWOOD, Greencastle, Ind.
Division of Botany

CARL H. EIGENMANN, Bloomington, Ind.
Division of Zoology

VERNON F. MARSTERS, Bloomington, Ind.
Division of Palaeontology

Directors of the Biological Survey of Indiana

1 July 1893.

So perhaps the Directors of the Survey were the formal, administrative organizers, and the BSC were the people who really knew the Biota of the State, or would do the fieldwork.

Pages 13-204 relate to the Biological Survey. Its major sections were as follows (numbers in parentheses are Proceedings' page numbers), and in the exact order of the Proceedings' pages:

1. *Botany* (14-19)—provides background information for the following plant sections.
2. Bibliography of Indiana Botany (20-30)—also includes information on early collectors, the stimulus provided by the publication of the *Botanical Bulletin* in 1875, later changed to the *Botanical Gazette.*
3. List of Plants (30-67)
   a. Cryptogams (30-64)—includes host information.
   b. Bryophyta (64-67)

4. *Zoology* (67-70)—provides background information on the following zoological sections.
5. Bibliography of Indiana Fishes (71-76)
6. The Fishes of Indiana (76-108)
7. Bibliography of Indiana Ornithology (108-116)
8. Notes on Indiana Birds (116-120)
9. Bibliography of Indiana Mammals (120-124)
10. Preliminary List of Indiana Mammals (124-139)
11. Mollusca (140-142)
12. Bibliography of Mollusca (142-145)
13. Species [of Mollusca] Described from Indiana (145-147)
14. General List of Mollusca (148-156)
15. *Geology*: Bibliography (156-191)
16. Suggestions for the Biological Survey (191-193)—Abstract [of a talk?] by John M. Coulter. It deals specifically with Phanerogams, but is also of general value. He recognized the existence of two categories of plants: indigenous and introduced. He suggests that each has its own unique collecting problems. He suggested that collectors be trained, and that their work be of two types: to collect all species growing in their district; and to carry out detailed studies of those most interesting plants. He stated that, "in work of this kind the following points must be made out:
    1. Mass distribution [abundance] . . .
    2. Topographical distribution . . .
    3. Geological distribution . . .
    4. The effect of man's presence . . ."
17. The Phanerogamic Flora of Indiana (193-199)—An article by Stanley Coulter about the form and content that a phanerogamic flora of Indiana might take.
18. Relation of Indiana High Schools to the Biological Survey—A stimulating article by W. S. Blatchley, parts of which are still germane today.

1894

The two committees and members remained unchanged from last year.

Papers read at the meeting (pages 27-143) included many that deal with the biological survey of Indiana.

The Biological Survey's Report (pages 144-178) was restricted only to plants. It was divided as follows (page numbers in parentheses):

Botany (144-147)
Appendix A: List of additions to State Flora (147-153)
Appendix B: Host plants of fungi (153-154)
Appendix C: Notes on the species reported previously (154)
Appendix D: List of Parasitic Fungi (154-156)
Flora of Hamilton and Marion Counties, Indiana (156-176).

1895

The Proceedings included publication of a two-page Act for the Protection of Birds, Their Nests and Eggs. Approved March 5, 1891 [but by what body?].

A plea for State support for publishing the Proceedings was made. While the list of Committees for 1895-96 retains the, "Directors of Biological Survey" (consisting of Eigenmann, Marsters, and Arthur), no listing is given for the earlier, separate committee, "Biological Survey."

A relevant paper read by John S. Wright at the winter meeting was, "Botanical Literature of the State Library."

The State Biological Survey Report actually consisted of 29 papers (pages 135-296), four of which are presented in title only. Eighteen dealt only with Turkey Lake (or Lake Wawasee), Kosciusko County, the site of Indiana University's Biological Station.

1896

Membership of the committee of Directors of Biological Survey remained unchanged. Thirty-four papers on botanical or zoological subjects were read, many of which related to the State's biota. In addition, 11 papers were separated as the second report of the Biological Station on Turkey Lake.

No meeting reports, in which the Biological Survey Committee was discussed, were included in these and the Proceedings of the last few years.

1897

Membership of the committee of Directors of Biological Survey remained unchanged.

Thirty-three papers were read on botanical or zoological subjects, many of which concerned the State's biota.

No mention or contribution concerned the Biological Survey Committee specifically.

1898 and 1899

Membership of the committee of Directors of Biological Survey remained unchanged.

Papers were read on botanical or zoological subjects, many of which concerned the State's Biota.

No mention or contribution concerned the Biological Survey Committee specifically.

Comments by the Author on the Beginning of Biological Surveys by the Indiana Academy of Science: 1891-1899

As we obtain a feeling for the multifaceted purposes and accomplishments of the first nine years of the Biological Survey Committee, one cannot help being struck by the great similarity with needs of our society today, and the resurgence of interest in the Biological Survey Committee today. In recent decades the Committee concentrated on assembling a bibliography of articles on the biota of the State. But in the last few years, spurred on by increased concern for the environment (and laws to enforce this concern!) and by projects such as Flora North America, the need for a Biological Survey that does more than keep track of relevant literature has become more apparent. In fact, interestingly enough, what is needed is nothing more than the original set of purposes of the Committee, as stated in the 1893 Report (see its reproduction above, under 1893)! The proposal for a computerized Flora Indiana Project adopted in the fall, 1975, by the Academy really is a step towards satisfying the original goals of the Committee, even down to involving high school teachers and students in it!

1900-1909 (James R. Gammon)

In none of the documents were there any reports of this committee. In each volume of the Proceedings there were papers that seemed to be pertinent to the Biological Survey, and those thought appropriate for the activities of the committee are listed.

1900

Directors of the 1900 Biological Survey were: C. H. Eigenmann, D. Bodine, V. F. Marsters, M. B. Thomas, J. C. Arthur, and S. Coulter.

J. T. Scovell—The Flora of Lake Maxinkuckee. A very good description of the lake at that time, the various kinds of plants and the abundance and location of these plants.

S. Coulter—Addition to the Flora of Indiana. There seemed to be at that time a lot of notes on this; it was a period when the corners were being filled in as to what was in the state of Indiana.

T. Large—The Methods and Extent of the Illinois Icthyological Survey. This paper discussed what was to become a rather extensive and ambitious work over in our neighboring state. This did not have anything to do with Indiana, but it was presented in the Proceedings.

1901

Directors of the Biological Survey were: C. H. Eigenmann, D. Bodine, M. B. Thomas, J. C. Arthur, and S. Coulter.

Listed are papers that were written from reports at the Biological Station at Winona Lake, a Series of, "Reports from the Biological Station" under the direction of C. H. Eigenmann.

A. A. Norris wrote two of the reports—Maps of Winona, Pike, and Center Lakes and The Mollusca of Winona Lake.

E. B. Williamson—The Dragonflies of Winona Lake.

H. W. Clark—The Flora of Eagle Lake and Vicinity.

Lucy Youse—Plant Ecology of the Winona Lake Region.

These were extensive papers with many photographs of the area.

1902

C. H. Eigenmann, D. Bodine, M. B. Thomas, J. C. Arthur, and S. Coulter served as Directors of the Biological Survey.

Amos Butler reported some rare birds, including some that we do not think of as ever having been in Indiana: the White Pelican on the White River in Knox County; Wood Ibis at Montezuma; Little Blue Heron found near Bainbridge; and the Passenger Pigeon near Larrel, Indiana. These were few in number and were shot by various hunters. There seemed to be much shooting in those days and there were no game laws. Birds that were shot were brought to the attention of Amos Butler himself.

Reports from the Indiana University Biological Station at Winona Lake under the direction of Dr. Eigenmann follow:

W. J. Moenkhaus reported a new species of darter.

F. Mutchler—The Myxomycetes of Lake Winona.

Chancey Juday—The Plankton of Winona Lake. (The author is now familiar with Juday's work and suspects that, "The Plankton of Winona Lake" may have been his first paper. Further, he did a great deal more work in Indiana before joining Dr. E. A. Birge at Wisconsin. The two of them working with others laid the foundation of modern limnology in this country.)

C. H. Kennedy provided a list of the dragonflies of Winona Lake.

1903

Directors of the Biological Survey were: C. H. Eigenmann, S. Coulter, M. B. Thomas, C. R. Dryer, and M. T. Cook.

The President's Address was presented by W. S. Blatchley, who has an honored place in Indiana. The address was entitled, "The Indiana of Nature; Its Evolution." In this paper he went from practically the formation of the earth in very broad strokes to a look at Indiana through the ages up to the present time. He referred more than once to man as that "prince of parasites." He described man as, "the greatest devastator that nature has ever known." At the end he described white man's devastation of the biota and decried what he regarded as a greedy waste of limited natural resources such as oil and natural gas.

The year's papers included:

Herman B. Dorner—Additions to the Flora of Indiana.

Charles Piper Smith—Bird Notes from the Indiana State Forester Reservation. (The author believes he was a student at Purdue at this time and that he provided notes and brief descriptions for several years after. Not all of his notes and brief descriptions got into print, but he did report them at meetings.)

T. J. Headlee and J. Simonton—Ecological Notes on the Mussels of Winona Lake. There were very good photographs of the species collected and a map of the lake showing where the species were found. This paper was well done and could be referred to today.

Amos W. Butler—Conditions Effecting the Distribution of Birds in Indiana. He mentioned the disappearance of the Ivory-billed woodpeckers and a great scarcity of many other species which were formerly abundant.

1904

Directors of the Biological Survey were C. H. Eigenmann, S. Coulter, C. R. Dryer, M. B. Thomas, and J. C. Arthur.

Most of this volume consisted of Waldo Lee McAtee's paper entitled, "Ecological Notes on the Birds Occurring within a Radius of 5 Miles of the Indiana University Campus." This included migratory records and photos of nests and of birds found in the Bloomington area at that time.

The only other paper that would have been of interest to the Biological Survey was Mr. S. Coulter's list, "The Poisonous Plants of Indiana." This paper did not provide any information on distribution but, nevertheless, might be of interest.

1905

The Directors of the Biological Survey remained unchanged.

Four papers contributed information about distributions, flora, and fauna.

C. P. Smith—Notes upon some little known members of the Indiana Flora. (There were a lot of notes published in those days.)

G. W. Wilson—Notes on some new or little known members of the Indiana Flora.

Charles Deam—Additions to Indiana Flora. (Mr. Deam was a scientist of some regard at that time.)

Will Scott—The Leesburg Swamp. (Scott would later go on to become a member of the Indiana University Zoology Department and work on fish and aquatics.)

1906

C. H. Eigenmann, S. Coulter, C. R. Dryer, M. B. Thomas, and J. C. Arthur continued to serve as Directors of the Biological Survey.

Papers of interest follow:

F. D. Kern—Parasitic Plant Diseases Reported for Indiana.

Charles C. Deam—Additions to Indiana Flora No. 3.

Amos W. Butler—Some notes on Indiana Birds. Most of this paper consisted of records of Snowy Owls, which during the previous year had been found with considerable abundance through much of Indiana. It may have been a cold winter. These and all the other birds he reported on, or at least a great deal of them, were brought to the attention of scientific people by hunters. Apparently, at that time, there was much random shooting of anything that moved.

1907

The same Directors continued their work in Biological Survey.

Two papers qualify for inclusion as topics of interest to the Survey, which do not have personal appeal.

G. W. Wilson—The Peronosphorales of Indiana. These are fungi parasitic on higher plants.

M. T. Cook—The Insect Galls of Indiana. At the time, apparently not much work on insects was being done.

1908

C. H. Eigenmann, S. Coulter, C. R. Dryer, M. R. Thomas, and J. C. Arthur were the Directors of the Biological Survey.

There were only two papers given, which seems to indicate a distinct drop in activity.

A. G. Johnson—On the Heteroecious Plant Rusts of Indiana.

Robert Hessler—Notes on the Flora of Cass County.

1909-1917 (Morris Levy)

During the period 1909-1917, the Biological Survey Committee was composed of many of the historically most eminent biologists that Indiana has nurtured. The chairmanship saw the consecutive four-year tenures of Stanley F. Coulter and Charles C. Deam, and the initial year of service by Herbert S. Jackson. Coulter, Deam, and Jackson were joined by Carl H. Eigenmann, Joseph C. Arthur, and James M. Van Hook to form the nucleus of monographers on the committee. Ecosystem analysts, Charles Dryer and Will Scott; systematists, Mason B. Thomas, Ulysses O. Cox, J. A. Nieuwland, H. W. Anderson, George N. Hoffer, Richard N. Holman; and an ecologist, M. S. Markle, comprised the balance of the membership. The majority of members were botanically oriented.

While the Academy members published voluminous reports in celebration of the twenty-fifth anniversary of the Academy (held in 1909) and the Century of Science in Indiana (1916), the Biological Survey Committee published only one official report during the period, in 1916. In this report, Chairman Deam presented the list of monographs of Indiana biota previously published by Indiana biologists. The list, which included new compendia for mammals, coleopterans, scale insects, fungi, and trees, was completed during 1909-1916. Deam emphasized that previous survey work on Indiana biota was exceedingly fragmentary. Faunistic surveys had concentrated on the conspicuous vertebrates (especially fish, reptiles, birds, and mammals), molluscs and selected insect groups (dragonflies, butterflies, orthopterans, coleopterans, and coccids). Surveys of herpetofauna and several economically important insect groups (especially moths, dipterans, and hymenopterans) had been conspicuously absent. Similarly, floristic surveys had concentrated on trees, ferns, shrubs, herbs, and various fungal groups and had largely ignored aquatic plants, bryophytes, lichens and mosses.

Papers published in the Proceedings by members of the Committee during 1909-1917 exhibit the flavor of most of the biological survey research conducted to this time, i.e., domination by biogeographic and taxonomic perspectives. The autecology, life history, and economic features of the biota were generally ignored or treated in anecdotal, empirical fashion; albeit with some notable exceptions in commercially important taxa. Chairmen Coulter and Deam pointed up the need for holistic approaches to the biological survey; but, pessimistically concluded that such an approach would be possible only when active support, both financial and professional, was forthcoming from the Indiana Legislature and State departments. The Committee recommended that a resolution be adopted by the Academy to present the rationale and organization which would achieve the desired goals of a state-wide biological survey to the Legislature and the Governor. There is no record that such a resolution or action was undertaken.

1918-1926 (Gayton C. Marks)

1918

The year was an unusual year for the Academy. The spring meeting was held jointly with the Illinois Academy of Science in the new state park at Turkey Run on May 24 and at the Shades on May 25. At this meeting, Professor S. H. [sic] Jackson reported on species of rusts found (in Indiana) and made a special appeal for the eradication of the barberry. This was now a war-time measure undertaken by every state in the Union.

Professor Herbert Spencer Jackson (1883-1956), Chief of Botany at the Agricultural Experiment Station of Purdue, was chairman of the Biological Survey Committee. Other members of the Committee were Richard M. Holman of Wabash (1886-1935), professor of botany; Millard S. Markle (1883-1968), professor of botany at Earlham; and Will Scott (1877-1937), assistant professor of zoology at Indiana University.

The 1918 fall meeting was canceled because of the influenza epidemic. The business meeting was conducted in early December in the Claypool Hotel in Indianapolis. The president of the Academy that year was Edward Bruce Williamson (1877-1933), cashier, and then president of the Wells County Bank of Bluffton. Williamson was later to serve on many committees, including the Biological Survey Committee. He had served as assistant secretary to the Academy 1910-1912 and again in 1915-1916. Among his other talents, he served as associate curator of Odonata at the University of Michigan from 1916-1928. A symposium was held on important contributions of science to military efficiency. Professor Holman was the leader for botany. The Committee on Biological Survey reported that, "a number of investigations are in progress." In the regular business meeting a motion was made and passed to appoint a committee to confer with a senator and a representative appointed by the governor to frame a bill for the naming of a state conservation commission. Among papers submitted that year were those of Paul Weatherwax, Charles Deam, and M. S. Markle.

1919

Members of the Committee on Biological Survey remained the same for 1919. The spring meeting was held at the State Forestry Reserve in Henryville. E. B. Williamson again served as President of the Academy. The bill establishing the State Conservation Committee went into effect April 1, 1919. The winter meeting was held on December 5 at the Claypool Hotel, Indianapolis. The Committee on Biological Survey reported through Chairman Jackson that its work throughout the year was chiefly to stimulate activity on the part of the persons engaged in work of the state biota. It had thus secured the promise of two papers for this meeting.

Two interesting resolutions were the product of the winter meeting of 1919. The first resolution was that the Academy go on record as favoring the blossom of the tulip tree as the state flower, rather than the carnation, which was made state flower by a state law enacted in 1913. The second resolution placed the Academy on record as "favoring and urging the compulsory use of the metric system in the United States at once and that the Secretary of the Academy be instructed to send a copy of these resolutions to the President of the United States."

The State Legislature at its 1919 session failed to appropriate anything for publication of the Proceedings for 1919 and 1920. Earlier law (1895) provided $600 annually for the Proceedings to be published in the quantity of not less than 1,500 nor more than 3,000 copies. Later the amount of support was doubled with the State providing $1,200 annually for the publication of the Proceedings. Among papers presented that year were those of Scott, Jackson, and Deam.

1920

Colonel Richard Lieber of the State Conservation Commission replaced M. S. Markle on the Biological Survey Committee in 1920. Lieber (1869-1944), known as the father of the Indiana State Parks, died at McCormick's Creek. Richard M. Holman served as Assistant Secretary of the Academy in this year. E. B. Williamson served on two committees, Nominating and Auditing. The spring meeting was held in the vicinity of Spencer with business session convening in the Christian Church.

At the winter meeting held in the Claypool Hotel, Indianapolis, the secretary reported for Chairman H. S. Jackson of the Biological Survey Committee that "no specific steps have been made to gain the cooperation of the State Conservation Commission in a systematic survey." A paper was presented by Charles Deam on plants new to Indiana, and some notes on termites were given by Harry F. Dietz (1890-1954). The latter was to serve as Assistant Secretary in 1921 and on many committees thereafter, including the Biological Survey. Dietz was an entomologist, first with the U.S. government, then later, Assistant State Entomologist. Three papers were delivered by H. S. Jackson at this meeting.

1921

In 1921, John J. Davis (1885-1965) of the Agricultural Experiment Station of Purdue replaced Holman on the Biological Survey Committee.

He was also to serve as Editor for the years 1922, 1923, 1924, 1925, and 1926. The May 27 and 28 Spring Meeting of the Academy was held jointly with the Indiana Audubon Society and the Nature Study Club of Indiana, in Fairview and Holiday Parks, Indianapolis. Fort Benjamin Harrison was visited on the second day. The business session was conducted at Ma-Lo Place in Indianapolis. After the business session, E. B. Williamson entertained with a large number of lantern slides of the country in South America where he had been collecting dragonflies.

In the Winter Executive Committee Meeting at the Claypool Hotel, Chairman Jackson of the Biological Survey Committee revised his previous announcement concerning the relationship of the Committee to the Conservation Commission. He announced that Mr. Lieber of the Commission had been made part of the Biological Survey Committee. Apparently after some discussion, the desirability of making a State Biological Survey prompted an effort by the Academy to obtain a special appropriation for this work. Jackson urged that a committee of more influential members should be selected to go before the State Legislature for this purpose. The following were members selected to represent the Biological Survey: Robert W. McBride (1842-1926), a former member of Lincoln's personal body guard; Frank B. Wynn (1860-1922), an active member of the Academy and an officer of the AMA; Amos William Butler (1860-1937), founder and Past President of the Academy and seven years its secretary; and M. S. Stanley Coulter, born in China and later known as "Stanley." He was Past President and Acting Assistant Secretary in 1892-1893. Stanley Coulter, the last remaining charter member of the Academy, died in 1943. His maternal grandfather was the founder of Hanover College. His older brother, John is well known for his botanical work at the University of Chicago. Both brothers served for many years on the Executive Committee of the Indiana Academy of Science.

Past, present, or future members of the Biological Survey Committee to hold executive posts of the Academy or to serve on other committees were: Harry F. Dietz, Assistant Secretary and Membership Committee; and E. B. Williamson, Nominating, Auditing, and Interstate Meetings Committees. Judge McBride announced that, at the request of the Academy, the tulip tree became the state flower. Papers submitted at the winter meeting of the Academy included those by Deam, Jackson, Scott, and John J. Davis. At the regular business session Mr. Lieber called the attention of the Academy to the very poor facilities of the State Museum. It was resolved that a portion of the proposed Soldier's Memorial should be devoted to the State Museum.

1922

The membership of the Biological Survey Committee remained the same for 1922. The spring meeting was held at French Lick in mid-May and the winter meeting at the Lincoln Hotel, Indianapolis. There was no report of the Biological Survey Committee that year.

Editor of the Proceedings was John J. Davis; Assistant Secretary was Harry F. Dietz. Dietz also served on the Membership and Publications Committees. Among those to submit papers that year were Markle, Deam, Jackson, and Marcus W. Lyon, Jr., Frank Barbour Wynn, M.D., long active in much of the work of the Academy, died on July 22.

1923

While the membership of the Biological Survey Committee remained the same in 1923, Will Scott replaced H. S. Jackson as Chairman. The spring meeting in May was held in Brookville, Indiana, the birthplace of the Academy. At this meeting a special committee was appointed to investigate and propose means most feasible for the preservation of wild flowers of the State. The committee consisted of David Myers Mottier (1864-1940), M. W. Lyon, Jr., H. S. Jackson, and C. C. Deam.

The 39th Annual Winter Meeting was held at DePauw University, December 6-8. The Biological Survey Committee had no report. Chairman D. M. Mottier reported for the committee appointed to investigate feasible methods for protection of wild flowers of the state that it was the concensus of the Committee that certain wild plants should be conserved and protected. Laws of Illinois and Vermont were cited and a law was proposed for Indiana. It was decided to read the report at the business session the next day. When presented to the general session, it was moved and carried that this special committee be empowered to call in such aid as it saw fit.

Papers submitted that year included the work of Deam, Weatherwax, Lyon, J. J. Davis, and Will Scott.

1924

Charles Clemon Deam (1865-1953) became President of the Academy in 1924. His Presidential address dealt with the flora of Indiana. He was also State Forester and had been Program Chairman for the Academy. Editor of the Proceedings was John J. Davis. Press Secretary Dietz served on the State Library and Membership Committees. M. S. Markle also served on the Membership Committee. On the Advisory Council was E. B. Williamson.

The new Biological Survey Committee was composed of Harry Dietz, Chairman, of Indianapolis; C. C. Deam, and E. B. Williamson, both of Bluffton. The spring meeting was held at the Opera House in Marengo, Indiana, in mid-May. The weather was ideal and Secretary Flora Anderson reports, "this is the best spring meeting the Academy ever had."

The 1924 winter meeting of the Academy was held at Purdue University December 4-6.

Chairman Dietz of the Biological Survey Committee reported on a meeting of that Committee on November 6, in Bluffton, and a list of projects drawn up at that time. An effort was to be made to secure companion volumes to Deam's *Trees of Indiana*, *Shrubs of Indiana* and Evermann and Clark's *Fishes of Lake Maxinkuckee.*

One of the most desirable projects was to replace Butler's *Birds of Indiana*, which had been out of print for 15 years. Mr. Mannfield of the Division of Fish and Game of the Department of Conservation was aware of the need for such a publication and in a report to the Director of the Department urged that steps be taken to secure it.

Richard Lieber, formerly of the Biological Survey Committee and now Director of the Department of Conservation, informed the Chairman that negotiations were under way to secure the help of Dr. Butler in preparing this publication. For this purpose $1,500 a year for two years would be allowed by his department. A need for other publications was expressed. This included *The Mammals of Indiana*, and *Batrachians and Reptiles of Indiana.* Two thousand dollars for each publication was to be set aside. The problem seemed to be in securing a qualified Indiana scientist for each of these tasks. "The one thing the Biological Survey Committee [needs] more than anything else is some real manuscripts that are ready for the press."

A paper of general interest was presented on, "City 'Smogs' in Periods of General Fair Weather" by J. H. Armington of the U.S. Weather Bureau at Indianapolis. It is worthwhile to include two short quotes from this paper: "Smoke and fog combinations, recently called 'smog' ", and "At Indianapolis, however, smog of the most aggravated type occurred, beginning in the latter part of the night as smoke which later combined with fog and became so dense by the early morning hours as to necessitate the full complement of electric lights in the down-town office buildings." Papers delivered at the divisional meetings included those by Jackson, Weatherwax, and B. Elwood Montgomery.

1925

The 1925 Biological Survey Committee was changed only in that it included a fourth member, Marcus Ward Lyon, Jr. (1875-1942), a naturalist and pathologist of South Bend. Lyon served as treasurer of the Academy from 1927-1932 and President in 1933. Chairman Dietz also served on the State Library Committee; Markle on the Membership Committee; and Williamson on the Research Committee.

The spring meeting was held in Madison, Indiana at the Clifty Inn on May 14-16. C. C. Deam was unable to attend because of illness. Telegrams were sent to both Deam and E. B. Williamson. At the Executive Committee Meeting that winter, held at Hotel Deming at Terre Haute, Chairman Dietz stated that, "although the Biological Survey Committee had been active during the year, there was little to add to the report of last year."

J. J. Davis moved that the Committee determine through questionnaires to members of the Academy, the survey work being done in the state, and that a complete report be presented at the next meeting. This motion was carried. The divisional meetings were held at the Indiana State Normal School and the Rose Polytechnic Institute. Papers given were by Charles Deam, Winona Welch, J. J. Davis, M. W. Lyon, Jr., and Will Scott.

1926

The 1926 spring meeting was held at the Hotel Spaulding, Dunes Park, Michigan City, May 20 and 21. Professor Henry Chandler Cowles

(1869-1939) and Dr. M. W. Lyon gave interesting talks on the physiographic features and the biota of the dunes.

Harry Dietz served as Press Secretary and as a member of the Membership and State Library Committees. J. J. Davis, Editor of the Proceedings, also served on the Program Committee as did M. W. Lyon, Jr. C. C. Deam was a member of the Research Committee that year. The Biological Survey Committee remained unchanged.

At the winter meeting held at Ball State Teacher's College, December 2-4, Chairman Dietz reported a number of survey papers recently published and others in the process of publication by members of the Academy, including Blatchley's *Heteroptera of the Eastern United States,* Montgomery's *Studies of Indiana Dragonflies,* Deam's *Grasses and Sedges of Indiana,* and Myer's *Reptiles of Indiana.*

The Committee was asked to take action on the survey questionnaire requested in the previous annual meeting.

Papers given that year were authored by Lyon, J. J. Davis, and Scott.

Judge Robert Wesley McBride, soldier, attorney, naturalist, and taxidermist, died on May 15, 1926. He became a member of the Academy at its founding in 1885. He remained active as an Academy member and helped to found the Indiana Audubon Society.

1927-1935 (Irene Horner)

1927

The Committee membership totaled four: Harry F. Dietz, chairman; Charles C. Deam; E. B. Williamson; and M. W. Lyon, Jr. Their main concern was promoting survey studies of biological taxa. Chairman Dietz noted with satisfaction that much survey work was being conducted in the state; among them were those reported in the Proceedings: Amos W. Butler on birds; Stewart Springer on reptiles and amphibians; Albert A. Hanson on weeds; Charles C. Deam on rare plants; F. M. Andrews on lichens and flowering plants; J. M. Van Hook on fungi; Otto Behrens on ferns; K. D. Doak on insects; J. J. Davis on insects; Samuel E. Perkins, III, on birds; and F. H. Test on birds. Dietz urged other members of the Academy to prepare articles in the following areas: Mammals, birds, reptiles, amphibians, fishes, insects, and molluscs of the state, similar to the articles by Deam on the trees and shrubs of Indiana and by Evermann and Clark on the fishes of Lake Maxinkuckee. The Committee recommended that Deam continue the study of flowering plants and ferns. They also stressed the need to study mosses, liverworts, and the larger fungi.

Two articles appeared in the 1927 Proceedings that proved to be prophetic. Louis A. Test and Frederick H. Test reported sighting the starling in Indiana, which was introduced to the United States in 1890 when 80 birds were freed in Central Park, New York. The Tests observed: "It will be interesting to note what effect they have upon the native wild birds. . . . So far, they seem to be confined to the open country and to avoid the town."

In the second article Mrs. Louise S. Swain reported her sightings of starlings, then quoted Mrs. Mable Osgood Wright of Connecticut:

"Here in Connecticut starlings were not conspicuous until 1900, but now they are a serious menace both to the summer resident birds, whose nesting sites they appropriate and to the winter food supply of our most beneficial resident birds. . . .

"Connecticut has done wisely in placing the starling on the list of unprotected birds, side by side with the English sparrow, but a concentrated country-wide effort must be made if the starling is to be kept in check. . . .

"If starlings were but few in number, their melodious spring whistle . . . would make them interesting guests, but as conditions are they are another warning of the foolishness of importing birds to another habitat than their own. Nature resents this meddling and the innocents pay for the mistakes of the rash."

At the spring session at New Harmony the Academy adopted a resolution presented by Dr. Lyon. The resolution was against changing the International Rules of Zoological Nomenclature, unless the Zoological Commission unanimously recommended the change to the International Zoological Congress.

In their report to the Academy, the Biological Survey Committee recommended the establishment of an Academy-supported collection of specimens for research and study of the state's biota. Such a collection would be housed at a state university or at Indianapolis. They also believed that the high schools should maintain labelled collections of local biota.

Plans for the coming year included mailing out a questionnaire to the Academy members to determine what fields of biology were being studied and the relation of such studies to the biological survey.

1928

Membership in the Biological Survey Committee included the four from the previous year, in addition to Sidney R. Esten. Under the direction of Chairman Dietz, the questionnaire had been mailed, and results were to be compiled in a report at a later date.

Survey papers published in the Proceedings included ones by Winona Welch, C. Mervin Palmer, J. M. Van Hook, J. J. Davis, and B. E. Montgomery.

1929

No changes occurred in the membership of the Committee. Because of the absence of Chairman Dietz, no report was submitted. The Academy appointed Stanley A. Cain, Editor, to tabulate the results of the survey for publication in the 1929 Proceedings.

Pages 15-17 presented the results of the questionnaire, listing the Academy membership under the following divisions: Conservation; popular science writing; botany; bacteriology (as related to public health); zoology; and paleontology. The members indicated whether they: 1) keep a bibliography of papers on the special fields listed, with references to the Indiana biological survey; 2) maintain a collection open for inspection; or 3) have published on the subject.

Survey papers presented included those by: F. M. Andrews; Winona H. Welch and Glady Price; J. M. Van Hook; F. H. Test; R. F. Daubenure; H. J. Lee; E. R. Cumings; J. J. Davis; and B. E. Montgomery.

1930

Chairman Dietz's resignation from the committee brought Charles C. Deam in as chairman. He headed a committee composed of E. B. Williamson; M. W. Lyon, Jr.; S. R. Esten; plus new members, J. J. Davis and J. M. Van Hook. Under the enlarged group's direction, new policies and emphases emerged.

In line with their interest in Indiana flora and fauna, the Biological Survey Committee urged the State Conservation Department to continue its commendable policy of preserving original tracts of land, which would maintain important ecological habitats. They also approved the Department's establishment of a museum of local natural history and geology at Turkey Run Park.

Among their other concerns was the use of common names in the nomenclature. One case noted concerned the common name of *Quercus muhlenbergi.* Since "Pigeon oak" was in use in the literature and since *Q. muhlenbergi* was the preferred food of the extinct passenger pigeon, the Committee recommended official recognition of "Pigeon oak" as the common name for this species to the Botanical Society of America and to the American Forestry Association.

Because most of the material representing the flora and fauna of Indiana was privately owned or in out-of-state museums, the Committee volunteered to prepare a bibliography of publications dealing with the taxonomy and distribution of the past and present flora and fauna of Indiana. In view of this situation, they reiterated their previous recommendations for establishing a research museum supported by the state for the preservation of specimens.

The Committee considered sending out a new questionnaire to the members of the Academy to be reported on at the next annual meeting. This questionnaire apparently intended to update the information received in the one sent out in 1928.

Surveys published in the Proceedings included ones by F. M. Andrews, Rexford F. Daubenure, C. C. Deam, C. Mervin Palmer, Winona Welch, Helene L. White, Willard Berry, F. M. Baumgartner, J. J. Davis, S. R. Esten, B. H. Grave, B. E. Montgomery, and Jean Piatt.

1931

In view of the Biological Survey Committee's interest in promoting student participation in biology, 1931 was a notable year. A committee was formed to organize a junior academy of science, drawing participants from high school science clubs.

This year was an active year for the Committee, with a sizable turnover in membership. The chief work of the Committee was preparing the bibliography of the state's flora and fauna. M. W. Lyon, Jr., presided as chairman. Sidney R. Esten was in charge of compiling a bibliography of vertebrates and invertebrates, except arthropods; Paul Weatherwax, the flora; and B. E. Montgomery, the arthropods. T. C. Yunker and C. F. Adams also served on the Committee. The Academy allowed the Committee $200 for clerical aid to assemble the work. Titles followed the form used in *Biological Abstracts* and were listed with notations by the compiler. The plan was to publish the bibliography in taxonomic sequence and give each compiler authorship credit.

In addition to work on the bibliography, the Committee re-endorsed the State Conservation Department's policy of habitat preservation and urged the state universities to provide adequate facilities for organizing and permanently housing specimens of Indiana habitats. This latter proposal marked a departure from endorsing an Academy-supported collection.

1932

B. Elwood Montgomery replaced Dr. Lyon as chairman, but the membership remained essentially unchanged. The Committee appeared to be occupied wholly with the bibliography and requested an additional $100 for its compilation costs.

Again, the Biological Survey Committee urged the state universities to provide facilities to preserve specimens of the state's flora and fauna.

Survey papers published in the Proceedings were authored by: M. E. Britton and B. H. Smith, C. C. Deam, Louise M. Lover, Robert L. Rogers, J. E. Potzger, John M. Amos, J. J. Davis, Howard O. Deay, and L. A. Test and F. H. Test.

1933

M. W. Lyon, B. E. Montgomery, S. R. Esten, and P. Weatherwax remained on the Committee, in addition to C. F. Adams and Clyde Malott. Dr. Lyons again became chairman. The bibliographical work had progressed as follows: The Arthropoda was completed except for two orders of the Insecta; the Mammalia, Reptilia, and Amphibia were completed with Aves and Pisces partly done; the Algae, Bryophyta, Pteridophyta, and Spermatophyta were completed, but no work was done on the Fungi.

The Biological Survey Committee recommended to the Academy that its influence be used to insure publication of manuscripts dealing with Indiana biota. The Committee also wanted the Academy to encourage younger students in their pursuit of research and scientific writing.

Among the survey studies published in the Proceedings were those by C. C. Deam, J. E. Potzger, J. J. Davis, B. E. Montgomery, and L. A. Test and F. H. Test.

1934

Emphasis continued on compiling the bibliography of Indiana flora and fauna. The Committee consisted of B. E. Montgomery, Winona

Welch, and C. M. Palmer, chaired by M. W. Lyon. They reported little work having been completed. However, Dr. Malott had nearly finished a bibliography of fossil biota, while Dr. Montgomery was the only "collaborator" to make progress in the work on the Arthropods.

The morale of the committee for their work appeared to be waning, as attested by these statements included in their annual report:

"The different members of the committee and the collaborators, not seeing any immediate outlet for publication, are not very enthusiastic about doing work which must remain unprinted for an indefinite period of time. Bibliographic work is of such a nature that additions have to be made from time to time as new titles appear."

Regarding the final deposition of the work, the Committee suggested that arrangements be made with the state library to house the bibliography and to keep an account of those who would retain parts of it.

In a more positive vein, the Academy authorized publication of the bibliography by Barton W. Everman, assisted by Dr. W. S. Blatchley. The work appeared in the forty-fourth volume of the Proceedings on pages 39-42. A botanical section contributed by M. S. Markle followed on pages 43-44.

The Committee recommended that a fireproof museum be built to store specimens collected in the state, noting that that would prevent loss of specimens currently being sent to out-of-state museums.

C. C. Deam, J. M. Van Hook, M. E. Britton and B. H. Smith, A. R. Bechtel, J. E. Potzger, J. J. Davis, Will Scott, L. A. Test and F. H. Test, B. E. Montgomery, Howard Deay, and George E. Gould contributed survey studies to the Proceedings.

1935

The same four members remained on the Committee. The tone of their report remained essentially the same as that of 1934. The bright spots were that a report of Indiana mammals with a complete bibliography was in press for the *American Midland Naturalist*, Volume 17, No. 1, 1936; and that Deam's flora of Indiana was near completion. There was still emphasis on the survey role of the Committee, as evidenced by the above report.

The Committee reported that the most complete and up-dated bibliography was on insects, which was maintained by Dr. Montgomery. Dr. Welch was keeping the bibliography of the bryophytes. Plans were being considered to keep the work in the state library and to keep an account of those who retain parts of it.

This recurring cry of the nine-year period seems to be a fitting end to this part of the Biological Survey Committee's history: "A great deal of valuable material has been sent out of the state to other museums for lack of a suitable place for its preservation here. Some of our sister states, notably Illinois and Michigan, have excellent facilities for the care of scientific specimens."

MICROBIOLOGY AND MOLECULAR BIOLOGY

Chairman: HAROLD EDDLEMAN, Box 378, Route 1, Palmyra, Indiana 47164

Chairman-Elect: DAVID C. MADSEN, Lobund Laboratory
University of Notre Dame, Notre Dame, Indiana 46556

ABSTRACTS

Searching for Intestinal Flora Involved in Secondary Bile Acid Production in the Rat. DAVID C. MADSEN, BERNARD S. WOSTMANN, and MARGARET BEAVER, Lobund Laboratory, University of Notre Dame, Notre Dame, Indiana 46556.——The secondary bile acids hyodeoxycholate (HDC) and $_{\omega}$-muricholate ($_{\omega}$-MC) are present in conventional (CV) but not germfree (GF) rats and mice. HDC has been shown to be a precursor of $_{\omega}$-MC, formed by hepatic action. As these two bile acids constitute a major fraction of excreted bile acids, we have been searching for the bacterial species involved in HDC formation. We have examined defined combinations of common intestinal flora consisting of from 1-8 species: none of these have resulted in appearance of HDC or $_{\omega}$-MC. We were thus potentially facing a search involving innumerable permutations of combinations of intestinal species. If the responsible species were not a known or a common one, the task would be even more formidable. Bile acids of the gerbil are dissimilar to those of the rat. We used flora from the large intestines of gerbils to conventionalize GF rats. The subsequent appearance of HDC and $_{\omega}$-MC in feces would indicate that the species or capability involved was ubiquitous, and that the murine gut was favorable to HDC production. In fact, we have detected only $_{\omega}$-MC in feces from "gerbilized" rats. This is surprising, in view of the role of HDC in formation of $_{\omega}$-MC. Several possible explanations are discussed.

Selection of Mutants of Bacteriophage T4D Defective in Tail Fiber Morphogenesis. HAROLD L. EDDLEMAN, Indiana Biolab, Palmyra, Indiana 47164.——*In vitro* complementation was used to select mutants of phage T4D having tail fiber defects. Mutagenized wild type phage were grown at low multiplicity of infection (moi = .01) on *Escherichia coli* B. Cells infected by the desired mutants produced fiberless particles. Wild type phages were removed by low-speed centrifugation following their adsorption on bacteria.

Particles remaining in suspension were purified and concentrated by differential centrifugation. Fibers were attached to them by incubating the particles in a mixture containing fibers and any enzymes needed for their attachment. The product was plated on *E. coli* CR63 which permits growth of amber nonsense mutants.

Amber mutants were found in 7% of the plaques tested. Of 243 amber mutants isolated, 214 could be assigned to previously known genes. The remaining 29 strains appear to be defective in fiber synthesis but differ from previously described mutants and may represent mutations in one or more new genes.

Microbial Interactions in Soil Cropped to Beans. D. M. HUBER and A. L. ANDERSEN, Purdue University, West Lafayette, Indiana 47907, Michigan State University, East Lansing, Michigan 48823.——The most common association of microorganisms in the soil was one of compatibility, although mycoparasitism, necrosis, and lysis were observed. An apparent symbiotic association of *Fusarium* sp. with a bacterium was also observed. The intimate and compatible association of bacteria with most fungi may be an indication of a mycosphere phenomenon. Antibiosis of *Fusarium* was not demonstrated since most of the reported antagonists were either compatible with the *Fusarium* species encountered or not actively growing in the soil. *Streptomyces* sp. were the least compatible of all isolated organisms. These associations may influence the active growth, pathogenicity, germination, or survival of a specific organism in the soil.

The Elongation of Palmitic Acid by Cell-Free Extracts of Penicillium Chrysogenum. JILL ASHLEY and ALICE BENNETT. Results of previous research on whole-cell cultures of *Penicillium chrysogenum* have suggested that acetyl CoA, without being converted to malonyl CoA, supplies the two carbon units for the elongation of palmitic acid. The purpose of this study was to determine the mode of elongation of 1-^{14}C palmityl CoA by a 20,000 x g mitochondrial pellet from *P.* chrysogenum.

Acetyl CoA or malonyl CoA was incubated with radioactively-labeled palmityl CoA for 20 minutes. Avidin was added to some experimental reaction mixtures. The resulting fatty acids were saponified, extracted with hexane, methylated with diazomethane, and purified by thin layer chromatography. The methyl esters were separated and identified by gas-liquid chromatography. The radioactivity of each methyl ester was determined by liquid scintillation spectrometry.

Elongation of palmityl CoA was observed in the presence of acetyl CoA, but not in the presence of malonyl CoA. The addition of avidin produced a greater proportion of short-chained fatty acids at the expense of palmitic acid, but did not decrease the percentage of long-chained fatty acids produced.

A high proportion of label was recovered in the $C_{18:3}$ fatty acid, linolenic acid. This suggested that two pathways of linolenic acid synthesis may be operating in this organism.

Plant Diseases and Disorders in Indiana—1976

D. A. KOMM, D. H. SCOTT, W. R. STEVENSON, and P. C. PECKNOLD
Purdue University, West Lafayette, Indiana 47907

Abstract

This is a report of the plant diseases and disorders diagnosed in Indiana from September 1, 1975 to August 31, 1976. Anthracnose leaf blight, common rust, and Gibberella and Fusarium stalk rots were widespread corn diseases in the state during 1976. Brown spot, bacterial blight, and downy mildew were common soybean foliar diseases. Phytophthora and Rhizoctonia root rots of soybeans were common, but less severe in 1976 than in 1975. Barley yellow dwarf virus damaged barley, oats, and wheat. Take-all of wheat was widespread with yield losses in some fields of 30% or more. Phytophthora root rot, Fusarium root rot, crown rot complex, and bacterial wilt caused some losses to alfalfa.

A severe outbreak of leaf anthracnose on white oak and sycamore was the prominent disease of shade trees. Various root stress factors resulted in a decline of many common landscape trees. A frequent disorder of yew (Taxus) was root rot, due to poorly-drained planting sites and/or heavy, clay-type soil. The prevalence of fire blight on apple and pear increased over the previous two years. Numerous late spring freezes caused severe damage to both tree fruit and small fruit.

Severe losses from insect transmitted diseases such as bacterial wilt of cucurbits and virus diseases of muskmelon, greenbeans, and sweet corn were reported. Soil borne diseases included Fusarium wilt of eggplant, muskmelon, okra, spinach, tomato, and watermelon, charcoal rot and scurf of sweet potato, southern blight of tomato, and black dot root rot of potato. Prevalent tomato foliar and fruit diseases included anthracnose, bacterial leaf spot, early blight, late blight, and Septoria leaf spot. Common foliar diseases of cucurbits included anthracnose, Alternaria leaf spot, downy mildew, and powdery mildew.

Introduction

Plant diseases and disorders are diagnosed at the Purdue Plant Disease Diagnostic Clinic and throughout Indiana as a service to county extension agents, growers, homeowners, and others. This service provides a quick, accurate diagnosis along with suggestions for effective control methods and serves a vital role in a productive agricultural system. This paper is a record of plant diseases and disorders diagnosed in Indiana from September 1, 1975 to August 31, 1976. When this report is compared with others (1, 3, 4) it is possible to determine general trends in the increase, decrease, or stability of Indiana plant diseases and disorders. With this information, agricultural research, extension, grower, and consultant personnel can direct research activities, plan control programs, and choose plant varieties best suitable to resist prevalent diseases. Previously, plant diseases and disorders diagnosed in the Purdue Plant Disease Diagnostic Clinic appeared in the form of a compilation (1, 3, 4). A compilation will not be included with this paper, but is available from the authors upon request.

Methods

Plant specimens were submitted to the Plant Disease Diagnostic Clinic by county agents, homeowners, growers, and others, or were collected from Indiana fields by the authors. Diagnosis of each specimen was made on the basis of signs and symptoms or by isolation of the pathogen. Appropriate control measures were suggested upon completion of diagnostic studies.

Results

Agronomic Crops

Corn

Diseases: Fusarium ear rot was prevalent throughout the state while Gibberella ear rot was most prevalent in the northern half during the 1975 harvest. Gibberella ear rot was responsible for swine refusal of corn or feed made from corn grown in localized areas of northern Indiana. Howard and Cass counties had the most reported cases of swine refusal.

Most corn was planted early in 1976 and in relatively dry, cold soils. Consequently, seedling blights were common and more severe than in recent years. A relatively small percentage of early planted fields were re-planted due to poor stands which resulted from a combination of unfavorable environmental conditions and seedling blight. Anthracnose leaf blight was widespread in the southwestern, northwestern, and northeastern counties of the state in May and early June. The disease was severe in individual fields, especially where corn followed corn and reduced tillage practices were used. One seed production field of the inbred C-123 in Benton county was severely damaged by anthracnose leaf blight and suffered a total loss for seed production. Dry weather in July and August prevented the development of the stalk rot phase of anthracnose. Had sufficient rainfall occurred during this time, similar to that of 1975, this disease possibly would have been severe. Maize dwarf mosaic and/or maize chlorotic dwarf symptoms were prevalent on corn in the river bottom areas of southern Indiana; however, losses were minimal except in those fields planted to susceptible varieties. Common rust was epiphytotic throughout the state. Severe disease development did not occur until August, thus yield losses were negligible, except in a few seed production fields planted to highly susceptible inbreds. Stewart's disease was prevalent in southern Indiana but disease severity was light in spite of a mild 1975-76 winter and high flea beetle populations. Gibberella and Fusarium stalk rots were widespread during the fall 1976. Good harvest weather prevented severe lodging.

Disorders: Eratic germination, uneven early growth, and purple discoloration were common disorders directly related to cold, dry soils at and shortly after planting.

Soybeans

Diseases: Brown spot and bacterial blight were common early season diseases, but yield losses were negligible. Downy mildew was widespread in Indiana fields. The incidence of downy mildew and bacterial blight was 23 and 4 percent, respectively, higher in 1976 than 1975 (2). Phytophthora root rot was widespread, especially in northern Indiana, but damage was less severe in 1976 than in 1975 due to lack of adequate moisture during the growing season. Rhizoctonia root rot was a common early season disease, but losses appeared to be minimal. Soybean mosaic and/or yellow mosaic virus symptoms were observed on individual scattered plants in many fields throughout the state. While these virus diseases were common, disease severity was low and no significant yield losses were reported. Sclerotinia stem rot was found in three widely separated fields in Wabash county. This is the first report of this disease in Indiana for several years. Brown stem rot and stem canker were two additional diseases observed in several fields scattered over the state, but neither disease caused apparent significant yield losses. Due to the dry late summer and early fall, pod and stem blight was light, and soybean seed quality was very good.

Disorders: Early season chemical damage was widespread in 1976, but not as severe as in 1975.

Small Grains

Diseases: Barley yellow dwarf virus was widespread and damaging to barley, oats, and wheat throughout the state. Take-all of wheat was observed throughout the state and was severe in many individual fields, with yield losses being 30% or more. Patches of blackened heads, varying in size from several feet in diameter to nearly entire fields, were visible in over half of all Indiana wheat fields at harvest time. The blackened heads resulted from saprophytic fungi, *Alternaria* spp., *Cladosporium* spp., and *Epicoccum* spp., attacking the glumes of plants prematurely killed by take-all, barley yellow dwarf virus and/or frost. Epicoccum was the most common fungus associated with the discolored heads.

Loose smut, powdery mildew, and leaf rust diseases were found scattered, but light, throughout the state. The most important aspect of these diseases is that new races of each pathogen have developed, and all Arthur types of wheat are susceptible to the new races. Arthur types represent 93 percent of all wheat acreage in Indiana and over 70 percent of all soft red winter wheat acreage in the U.S.

Alfalfa

Diseases: Phytophthora root rot, Fusarium root rot, crown rot complex and bacterial wilt continued to cause problems in isolated fields throughout the state, but damage from these diseases was not nearly as severe as in 1975.

Shade and Ornamental Trees

Diseases: Leaf anthracnose was the most frequently recorded disease of landscape trees. Sudden cool, wet weather in early May caused a severe outbreak of anthracnose on white oak and sycamore; maple and ash were affected to a lesser degree. The incidence and severity of anthracnose was greatest in northern Indiana with only slight injury occurring in the middle and southern areas of the state. An increase in recorded and observed occurrence of Diplodia tip blight of pine was noted as compared to 1974 and 1975 (1, 3). Disease occurrence was most prevalent on well established plantings of Austrian and Scotch pine. An apparent increase in Dutch elm disease was seen in several northern counties during early summer. Stem canker diseases were most prevalent on Russian olive, willow, and oak. Unusually dry spring weather resulted in an overall decrease in the incidence and severity of many common leaf and stem diseases as compared with the past two years (1, 3).

Disorders: An early spring followed by numerous late spring freezes caused extensive injury to young expanding foliage and/or buds of many ornamentals. Maple, tulip tree, spruce, and pine were hardest hit judging by the number of recorded samples. Decline was the most frequently diagnosed disorder affecting landscape trees; as in past years, maple decline was most prevalent (1, 3). White pine, ash, oak, birch, dogwood, and mountain ash were other tree species frequently suffering from decline. Various urban stress factors along with spring and/or summer drought periods over the past few years appear to be responsible for much of the decline. Summer leaf scorch was severe during July and August; maple, dogwood, and mountain ash were most severely affected. Iron chlorosis was common on oak, especially pin oak, and sweet gum.

Ornamentals

Diseases: Dry weather during spring and summer resulted in fewer ornamental diseases than in past years. Most noticeable of the early spring diseases was rust on juniper. Cedar-apple, cedar-hawthorn and cedar-quince rust all were prevalent. Other diseases commonly diagnosed were Phomopsis tip blight of juniper, powdery mildew on Euonymous and lilac, bacterial blight of geranium, Fusarium basal dry-rot of Gladiolus, and Pyracantha scab.

Disorders: The most frequently received ornamental was Taxus. In most cases, plants showed yellow foliage and poor growth as the result of root rot. The cause of Taxus root rot was most frequently related to poorly drained planting sites and/or heavy, clay-type soil. This proclivity for root rot to occur on Taxus strongly indicates the need to plant this particular plant species in only well drained, light-textured soils. An early spring dieback of rose was prevalent in most areas of Indiana. The excessive amount of dieback was largely related to a long spell of warm growing weather in autumn which did not allow plants to become sufficiently hardened. Unusually warm periods in February followed by freezing weather in March also contributed to the dieback. Winter desiccation was prominent on holly, juniper, and arbor-vita.

Fruit Trees

Diseases: Numerous late spring freezes resulted in a reduced fruit crop throughout the state and consequently less noticeable disease problems. The most prevalent disease of apple and pear was fire blight. Black knot was the most common disease of plum. Occurrence of both fire blight and black knot showed an increase over the previous two years. Apple scab, cherry leaf spot, and peach leaf curl were other diseases of frequent record, however, field occurrence was light. No fruit rot of any consequence was noted as of September 15, 1976.

Disorders: All fruit disorders of importance were weather related. Frost rings, russetting, and fruit malformations, especially on apple, were common due to the many late freezes in spring. Hail damage was frequently diagnosed as causing moderate damage in various orchards throughout the state. There were a few isolated cases of herbicide injury on apple and peach caused by improper application of material.

Small Fruits

Diseases: Black root rot of strawberry was the most frequently recorded small fruit disease. Disease occurrence was usually associated with older strawberry plantings (3 to 5 years) in heavy soil; however, exact cause of the disease is not yet known. Black rot of grape was moderate to severe in various vineyards in southern Indiana. Raspberry anthracnose was lighter than that reported in the previous two years (1, 3). In general, there were no small fruit diseases of major importance during the 1976 growing season.

Vegetables

Diseases: Several insect transmitted diseases were common on vegetable crops throughout the state. In some cases, these diseases were responsible for severe losses. The unusually high frequency of insect borne diseases appeared to be related to weather conditions which favored winter survival or high seasonal populations of insect vectors. The most serious disease was bacterial wilt of muskmelon and cucumber caused by *Erwinia tracheiphila* and transmitted by the striped and spotted cucumber beetles. Plant losses of 10-20% in commercial muskmelon fields were not uncommon. Troublesome aphid borne diseases included cucumber mosaic virus on muskmelon, bean yellow mosaic virus on pole and bush green beans, and maize dwarf mosaic virus on sweet corn.

Soil borne diseases included Fusarium crown rot of asparagus, clubroot and yellows of cabbage, Fusarium wilt of eggplant, muskmelon, okra, spinach, tomato, and watermelon, charcoal rot and scurf of sweet potato, southern blight of tomato, and black dot root rot of potato. The latter disease caused by *Colletotrichum coccodes* has now been identified in all major potato production areas of Indiana and constitutes a major threat to the continued cultivation of susceptible potato cultivars. Fusarium wilt of muskmelon and watermelon was observed most frequently in southwest Indiana where hot dry weather accentuated symptom development.

Prevalent tomato foliar and fruit diseases included anthracnose, bacterial leaf spot, early blight, late blight, and Septoria leaf spot. An early season outbreak of tomato bacterial spot was favored by high winds and wind blown rain. Overall losses to tomato diseases were considered much less severe during the 1976 growing season than during the preceding year. Common foliar diseases of cucurbits included anthracnose, Alternaria leaf spot, downy mildew, and powdery mildew.

Disorders: Chemical injury, the most common disorder identified on several vegetable crops, was generally related to herbicide drift or improper pesticide application. The total number of vegetable specimens with chemical injury symptoms in many cases represented a reduction from the previous year.

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Hormone Effects on NADH-Oxidizing Enzymes of Plasma Membranes of Rat Liver

DEBRA P. GAYDA, F. L. CRANE, D. J. MORRÉ and H. LŐW
Department of Biological Sciences
Purdue University
West Lafayette, Indiana 47907
and
Department of Endocrinology
Karolinska Hospital
Stockholm, Sweden

Abstract

Hormone binding influences both oxidase activity and adenylate cyclase activity in the plasma membrane of rat liver. The findings suggest a coupling between redox function and adenylate cyclase. Furthermore, since NADH inhibits adenylate cyclase of PM, whereas NAD has no effect, the NADH dehydrogenase may act as a sensor for the oxidation-reduction state of the cell.

Introduction

Polypeptide hormones, growth hormones, and catecholamines bind with receptors localized on the outer surface of the plasma membrane. This binding of hormones has been correlated with the activation in adenylate cyclase of the inner membrane surface. Recently, Crane and Low have shown that a distinct NADH dehydrogenase exists in plasma membranes (2) and that it, too, is stimulated by hormones (4). The NADH dehydrogenase activity in the plasma membranes is influenced by glucagon, ACTH, fluoride, atebrin, and azide at concentrations which stimulate or inhibit the activity of adenylate cyclase (4).

The catecholamines (epinephrine, norepinephrine, isoproterenol) and azide activate adenylate cyclase activity (9,10) whereas the flavin antagonist, atebrin, inhibits adenylate cyclase activity (5). In this report, these known stimulators or inhibitors of the adenylate cyclase activity were tested for their effect on the oxidation of NADH with oxygen or juglone as electron acceptors. Membrane sources were plasma membrane from rat liver (PM), milk fat globular membranes (MFGM), smooth endoplasmic reticulum (SER), rough endoplasmic reticulum (RER), Golgi apparatus (GA), and mitochondria (MITO). Only in PM, did the effects of the stimulators and the inhibitor on NADH dehydrogenase correlate with their effects on adenylate cyclase. The other membrane preparations showed differences from PM with respect to stimulation or inhibition.

Materials and Methods

Membranes were prepared from rat liver as described: PM (11), GA (7), SER(7), RER(7), and MITO (7). MFGM (6) were prepared from cows milk.

Both NADH oxidase and NADH juglone reductase assays were based on oxygen uptake at 37°C monitored with an oxygen electrode. The reaction mixture contained in a final volume of 1.5 ml, membrane preparation, sodium phosphate buffer (0.03 M; pH 7), and an appropriate amount of test substance. Incubations were for 3 min. NADH (260 μg), with or without juglone (60 μg), was added to measure NADH oxidase or NADH juglone reductase, respectively.

Isoproterenol, epinephrine, 3,5,3′-triiodothyronine, propranolol, NADH and juglone were from Sigma Chemical Company. Norepinephrine and atebrin were from Aldrich Chemical Company.

Results

Atebrin (10^{-3}M) is a flavin antagonist that inhibits adenylate cyclase activity (3). When NADH oxidase activity in various membrane preparations was measured as a function of atebrin concentration (Fig. 1), NADH oxidase activity was inhibited in PM and MFGM. No inhibition of NADH oxidase was observed with GA, SER, or MITO. With GA, NADH oxidase was stimulated. Similar results were obtained with atebrin when NADH juglone reductase was measured (Fig. 2). Azide stimulated both NADH oxidase and NADH juglone reductase activity in PM (Fig. 3 and Fig. 4). Again the effect of azide on NADH oxidase and NADH juglone activity in the other membrane preparations was insignificant, except for MFGM. MFGM was inhibited by azide which may be due to higher amounts of xanthine oxidase contained in this type of plasma membrane (1).

A selected hormone, 3,5,3′-triiodothyronine (T_3) was tested for stimulation of NADH dehydrogenase with MFGM, PM, GA, RER, and MITO.

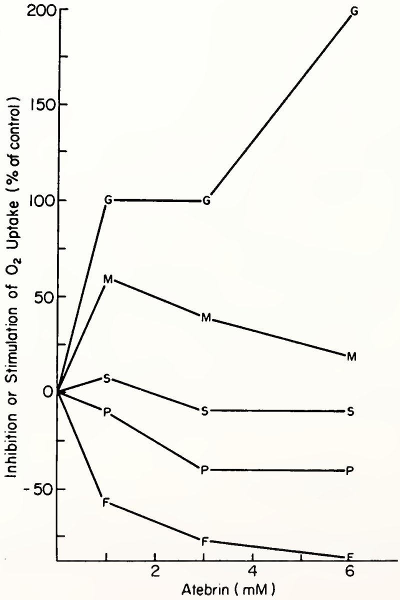

FIGURE 1. *The inhibition or stimulation of NADH oxidase activity with various membrane preparations when treated with atebrin. Control activity of membranes (nmoles/min/mg protein): P-plasma membrane, 14; F-milk fat globular membrane, 24; M-mitochondria, 13; G-Golgi apparatus, 10; S-smooth endoplasmic reticulum, 59.*

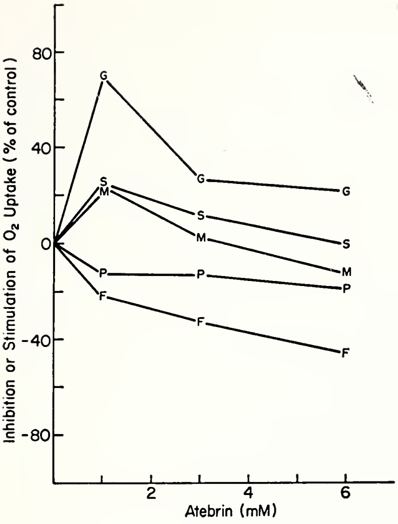

Figure 2. *The inhibition or stimulation of NADH juglone reductase activity with various membrane preparations when treated with atebrin. Control activity of membranes, (nmoles/min/mg protein): P-plasma membrane, 37; F-milk fat globular membrane, 290; M-mitochondria, 290; G-Golgi apparatus, 132; S-smooth endoplasmic reticulum, 720.*

NADH oxidase of T_3 (10^{-6}M)-treated PM was stimulated 250%, while that of T_3 (10^{-6}M)-treated MFGM was stimulated 80%. In contrast, no stimulation of NADH oxidase was measured in T_3-treated GA, MITO, or RER.

The β-adrenergic catecholamines stimulate the enzyme adenylate cyclase in virtually all tissue (10). The catecholamine, isoproterenol, (10^{-5}M) also stimulated NADH oxidase in PM and MFGM (Fig. 5). Isoproterenol gave successively less stimulation of oxidase with other membranes in the order GA, SER, RER and MITO. Furthermore, the

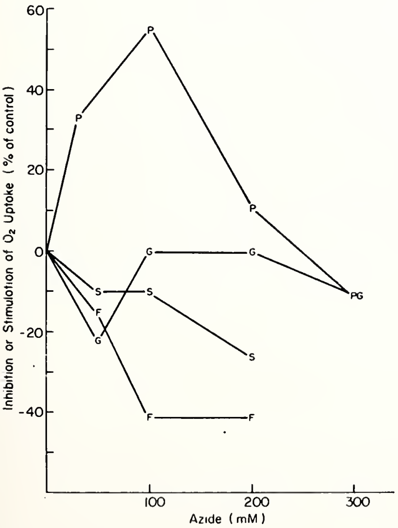

Figure 3. *The inhibition or stimulation of NADH oxidase activity with various membrane preparations when treated with azide. Control activity of membranes (nmoles/min/mg protein): P-plasma membrane, 25; F-milk fat globular membrane, 32; G-Golgi apparatus, 18; S-smooth endoplasmic reticulum, 38.*

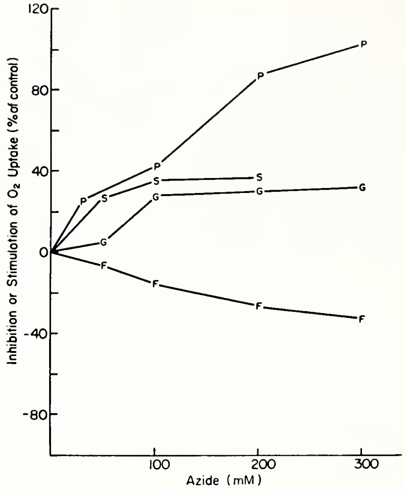

FIGURE 4. *The inhibition or stimulation of NADH judglone reductase activity with various membrane preparations when treated with azide. Control activity of membranes (nmoles/min/mg protein): P-plasma membrane, 390; F-milk fat globular membrane, 275; G-Golgi apparatus, 175; S-smooth endoplasmic reticulum, 1075.*

isoproterenol stimulating effect on PM and MFGM was inhibited by propranolol (10^{-3}M), a β-adrenergic antagonist.

The effect of two other β-adrenergic catecholamine agonists on NADH oxidase activity was measured with MFGM (Table 1). Epinephrine stimulated NADH oxidase 130%, whereas, norepinephrine stimulated NADH oxidase only 50%. Murad et al. (8) found stimulation of adenylate cyclase by the catecholamines in broken cell preparations.

The effect of an α-adrenergic agonist, phenylephrine on NADH oxidase was also tested with MFGM (Table 1). No inhibition or stimulation on NADH oxidase was found upon treatment with phenylephrine (10^{-6}M) or ephedrine, (10^{-6}M).

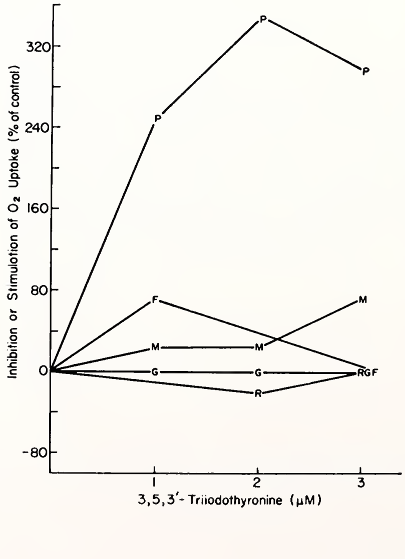

FIGURE 5. *The inhibition or stimulation of NADH oxidase activity with various membrane preparations when treated with 3,5,3'-triiodothyronine. Control activity of membranes (nmoles/min/mg protein): P-plasma membrane, 16; F-milk fat globular membrane, 24; M-mitochondria, 19; G-Golgi apparatus, 18; R-rough endoplasmic reticulum, 33.*

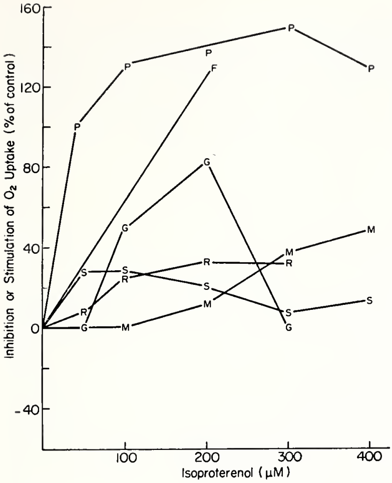

FIGURE 6. *The inhibition or stimulation of NADH oxidase activity with various membrane preparation when treated with isoproterenol. Control activity of membranes (nmoles/min/mg protein): P-plasma membrane, 22; F-milk fat globular membrane, 23; M-mitochondria, 19; G-Golgi apparatus, 18; S-smooth endoplasmic reticulum, 96; R-rough endoplasmic reticulum, 40.*

Studies on NADH dehydrogenase by Crane and Low showed effects of atebrin, azide, and T_3 on cytochrome C reductase activity and indophenol reductase activity (2). Atebrin inhibits cytochrome C reductase activity and indophenol reductase activity in PM, so it inhibits all NADH dehydrogenase activity. Azide and T_3, however, differ in their effects depending on the redox acceptor used. NADH cytochrome C reductase activity and NADH indophenol reductase activity are both inhibited whereas the NADH oxidase is stimulated by both T_3 and azide and NADH juglone reductase activity is stimulated by azide and not affected by T_3. Thus, PM has been shown to contain a distinct NADH dehydrogenase (2). It appears now that a connection between NADH dehydrogenase of PM and adenylate cyclase activity exists as well. A redox function in the coupling of hormone binding with the activation of adenylate cyclase is suggested. Since NADH inhibits adenylate cyclase of PM, whereas NAD has no effect (5), the NADH dehydrogenase may act as a sensor for the oxidation-reduction state of the cell and thereby function as part of a more complicated homeostatic control mechanism.

TABLE 1. *Stimulation or inhibition of NADH oxidase activity with adrenergic agonists on MFGM*

Adrenergic agonist	Stimulation (% of control)
isoproterenol	+150
epinephrine	+130
norepinephrine	+ 50
phenylephrine	0
ephedrin	0

Control activity of MFGM is 23 nmoles/min/mg.

Acknowledgments

Supported by grants from the National Institutes of Health, the National Science Foundation, and the American Heart Association. Liver fractions were prepared by Keri Safranski. Milk fat globule membranes were kindly provided by Prof. T. W. Keenan, Department of Animal Sciences Purdue University.

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Colicin El Induced Depolarization of the Bacterial Inner Membrane

J. MICHAEL GOULD and W. A. CRAMER
Department of Biological Sciences
Purdue University
West Lafayette, Indiana 47907

Summary

When a small pulse of oxygen is added to an anaerobic suspension of logarithmic phase *Escherichia coli* cells, the subsequent acidification of the medium which is observed in the absence of permeant charged ions is slow ($t_{1/2} = 10$ sec) as is its relaxation ($t_{1/2} =$ at least several minutes). The number of protons extruded for each oxygen atom added (H+/O) is small, varying from about 0.4 to about 1.0 depending upon the carbon source used for growth and the growth phase of the cells. Treatment of the cells with colicin El causes a large increase in the amplitude of the proton extrusion elicited by an oxygen pulse, so that the H+/O ratio attains values > 2.0 regardless of the cell growth conditions. In addition, the rate of proton efflux ($t_{1/2} < 1$ sec) and its relaxation ($t_{1/2} = 10\text{-}20$ sec) are greatly accelerated in colicin-treated cells. After addition of colicin El, the increase in the H+/O ratio has a time course which is very similar to the El-induced loss of K+ ($t_{1/2} = 3$ min). Furthermore, the effect of colicin El on the kinetics and extent of H+ efflux is dependent upon the presence of K+, in the medium, with an apparent "K_m" for potassium of about 0.5mM. The properties of the proton pulses measured in the presence of colicin El plus K+ are very much like those measured in cells treated with the permeant anion SCN⁻. rhus, these experiments provide direct evidence for a rapid, colicin El-induced depolarization of the bacterial membrane.

Introduction

Jacob *et al* (1) reported that colicin El inhibited growth and nucleic acid synthesis in a sensitive *Escherichia coli* strain while not inhibiting respiration. It was also found that this colicin inhibits a range of active transport systems (2). These observations, and that of an oxygen requirement for the action of this colicin, led to the hypothesis that colicin El is an uncoupler of oxidative phosphorylation [Levinthal and Levinthal, quoted in (2)]. This hypothesis was consistent with further studies on colicin inhibition of active transport (3,4) and with the observation of a rapid decrease in intracellular ATP levels caused by colicin (5).

However, it was also found that the efficiency of colicins El and K is not markedly decreased in anaerobic samples, as measured by the inhibition of active transport (5) and the colicin El-induced increase in fluorescence intensity of a lipophilic probe (6). These observations, together with the report that the effectiveness of colicins K and El was not changed in hemin-less mutants (5) implied that the action of these colicins does not necessarily require respiratory activity. An energized membrane, however, may be required for the action of all colicins (7,8), although the actual degree of required energization may be small (9), and this energization may be achieved through either ATP hydrolysis or respiration.

It has been proposed that the energy level of energy transducing membranes is controlled by the free energy stored in an electrochemical potential consisting of a proton gradient and/or an electrical potential across the membrane (10,11). According to this chemiosmotic hypothesis, charge separation generated through electron transport can generate a transmembrane potential, which can subsequently be relaxed by the movement of a proton through an energy transducing complex (e.g., ATP synthetase, transport proteins). At present there is disagreement with aspects of this model relating to the precise significance of the ion movements observed between the bulk aqueous phases separated by the membrane (12,13), and some of these problems are discussed elsewhere (14). However, the data presented here is not inconsistent with the existence of a local or transmembrane potential in the energized membrane of *E. coli*. In intact *E. coli* it appears that the dominant component of the electro-chemical potential at pH 7 is the membrane electrical potential (15,16). It is reasonable to expect, therefore, that the deenergization of the membrane by colicin would involve dissipation of this potential. In a system in which energy is stored primarily as an electrical potential, the appropriate movement of any charged species, not just protons, can serve to deenergize the membrane. Indeed, an event which appears to be closely related in time to the first biochemical events caused by colicin is an increase in K^+ permeability of the cell resulting in the leakage of intracellular K^+ into the medium (17-19,6,33).

Fluorescence studies with the probe 3,3′-dihexyloxycarbocyanine indicated that colicin K partially depolarized the cytoplasmic membrane (20). However, very similar fluorescence changes induced by colicin El (6), K (21), or Ia (22) have been reported for the lipophilic probe N-phenyl-l-naphthylamine (PhNap), although this probe will not respond directly to a membrane potential, and much of it is localized in the cellular envelope outside of the inner membrane prior to colicin addition (21). Thus, it is important to study the effect of colicin on the cellular membrane potential by an independent technique.

Mitchell and Moyle (23,24) observed that addition of an oxygen pulse to an anaerobic suspension of mitochondria causes an increase in the acidity of the suspension. In those experiments, and in similar experiments done with anaerobic bacterial suspensions (25-27) the amplitude and rate of the proton efflux after an oxygen pulse was increased in the presence of mobile, charge compensating counterions (e.g., SCN^-, K^+ plus valinomycin). According to Scholes and Mitchell (27), these counterions allow a larger and faster proton movement by dissipating the membrane electrical potential which is formed by the charge separation accompanying respiration-catalyzed proton efflux. In this paper we report that colicin El, in the presence of K+, causes an increase in the rate and extent of proton efflux after an oxygen pulse in a manner similar to SCN^-, and that this effect closely parallels in time the loss of K+ by the cells.

Experimental Methods

Bacteria. For most experiments reported in this paper, cells of the *Escherichia coli* strain B/1,5 were used. These cells were grown on a minimal medium (pH 7.0) containing (per liter): 1 g $(NH_4)_2SO_4$, 0.5 g sodium citrate, 0.1 g $MgSO_4 \cdot 7H_2O$, 7 g K_2HPO_4, 3 g KH_2PO_4, and trace metals according to Anraku (29). The carbon source was either 1% succinic acid or 1% glycerol (w/v). The growth media for the other *E. coli* strains used in this study were (per liter): strain JC411 (*col El*), 8 g casamino acids, 5 g yeast extract, 1 g glucose, 5 g NaCl (pH 7.0); strain A_{586} (*tol VIII*), 1 g NH_4SO_4, 10.5 g K_2HPO_4, 4.5 g KH_2PO_4, 0.1 g $MgSO_4 \cdot 7H_2O$, 1 mg thiamine, 20 mg proline, 20 mg histidine, 20 mg leucine, 20 mg threonine, 4 g glucose (pH 7.1) (ref.30); strain K12 1100 and strain ML 308-225, same as B/1,5 above.

Sterile 250 ml Erlenmeyer flasks containing 50-60 ml minimal medium and the desired carbon source were innoculated from overnight cultures, and incubated at 37° with vigorous shaking for 4.5-5.5 hrs (mid-logarithmic phase growth) or 14-17 hrs (stationary phase growth). Cells were harvested by centrifugation at 4°, washed twice in 150 mM KCl, 0.5 mM MOPS-KOH (pH 7.0) and resuspended in this medium to a final concentration of about 3×10^9 cells/ml. For experiments using the permeant anion SCN^-, the cells were washed twice and resuspended in a medium containing 100 mM KCl, 50 mM KSCN, 0.5 mM MOPS-KOH (pH 7.0).

For experiments involving colicin El treatment of cells, the colicin was added to the cell suspension in a small volume (2 μl) to a final concentration of 1 μg protein/ml. When cells grown with succinate as carbon source were used, it was necessary to add the colicins 5 min. before the initiation of anaerobiosis, presumably because of an energy requirement for colicin action. When cells grown with glycerol as carbon source were used, colicin could be added either before or after anaerobiosis with no difference in its effects. Cell survival after colicin El treatment was $< 0.1\%$.

pH Measurements. A 2 ml aliquot of the final cell suspension was placed in a water-jacketed, glass reaction vessel (3 ml capacity) which contained a small magnetic stirring bar. The top of the reaction chamber was sealed with a rubber stopper through which passed a Sargent miniature combination pH electrode. Small Teflon tubes also passing through the stopper allowed a continuous stream of water-saturated nitrogen gas to be passed across the surface of the cell suspension. Another small hole in the stopper permitted the insertion of the needle of a microliter syringe, which was used to make additions to the sample. The temperature of the reaction chamber was maintained at 33°C by a constant temperature circulating water bath.

The output from the pH electrode was amplified by a Corning Model 14 pH meter operated on the expanded scale. The electrometer output was recorded on a strip chart recorder with a scale expansion sufficient to give 0.01 pH units full scale (6 in). At this level of amplification, the noise level of the pH measuring system was $\leqq 2 \times 10^{-4}$ pH units. The overall half-response time for the system was on the order of 1 sec as measured by the recorded response to a rapid injection of HCl.

After the cell suspension had become anaerobic (approximately 15 min), small pulses of oxygen were added by the rapid injection of a small volume (usually 5-10 μl) of air-saturated, double distilled water. The time required to inject a 10 μl pulse was 0.1 sec or less. After an experiment the chart paper was calibrated in H^+-ion equivalents by titrating the sample with small aliquots of 0.001 M HCl. The H^+/O ratio was calculated from the maximum extent of the pH change after an oxygen pulse, assuming a concentration of 275 μmoles O_2/1 for distilled water at 23°C. No correction was made for any decay of the pH change which may have occurred during the proton efflux.

Changes in the concentration of K^+ in the suspending medium were monitored similarly using a glass Beckman cation electrode. The reference portion of the Sargent miniature combination pH electrode served as the reference electrode, except that the saturated KCl solution within the reference electrode was replaced with saturated NaCl. The cation electrode potential (in mV) was calibrated against known concentrations of KCl. The response was completely linear for K^+ concentrations $> 2.5 \times 10^{-5}$M, with a slope of 56 mV (33°C) per decade change in K^+ concentration.

Miscellaneous. Colicin El was prepared from the colicinogenic *E. coli* strain JC411 according to the methods of Schwartz and Helinski (31) except that the last CM-cellulose step was omitted. The lyophilized El was dissolved in M-9 salt medium and had a specific activity of approximately 1:50 on a protein basis. FCCP (*p*-trifluoromethoxy-carbonylcyanide-phenylhydrazone), kindly supplied by Dr. P. G. Heytler, was dissolved in ethanol. The cell strains used in this study were the generous gifts of Drs. D. Helinski (JC411 (*col El*)), H. R. Kaback (ML 308-225), S. E. Luria (A_{586} *tol VIII*), P. W. Postma K12 1000, and S. Silver (B/1,5).

Results

Effects of colicin El and FCCP on oxygen-pulse dependent pH changes.

The addition of a small pulse of oxygen to an anaerobic suspension of *E. coli* B/1,5 cells results in a brief period of electron transport which is accompanied by an acidification of the medium. The efficiency of coupling between this proton efflux into the external medium and the reduction of oxygen (H^+/O) ratio) is low in the absence of any additions to the resuspension medium, and is dependent upon both the growth phase of the cells and the carbon source used for growth [Fig. 1 and ref. (14)]. Cells grown on succinate and harvested in mid-

FIGURE 1. *The effect of colicin E1 on the rate and extent of proton efflux in* E. coli *following an oxygen pulse. Cells of* E. coli *strain B/1,5 grown on 1% succinate (a,b) or 1% glycerol (c,d) were harvested during mid-logarithmic phase growth. Colicin E1 (1 μg/ml), sufficient to allow < 0.1% survival, was added to (b) and (d) 5 minutes before the initiation of anaerobiosis. The oxygen pulses (upward arrows) contained 5.5 ng atoms O. An upward deflection of the pH trace represents an acidification of the medium.*

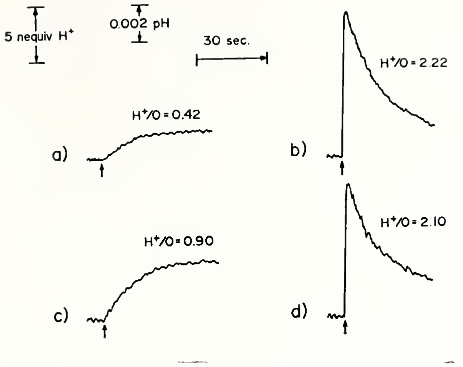


FIGURE 2. *Inhibition of net proton efflux by FCCP.* Left. *Cells of* E. coli *strain B/1,5 were grown on 1% glycerol to mid-logarithmic phase before harvesting. Upper trace, control; lower trace, with 5 μM FCCP. Right. Cells of* E. coli *strain B/1,5 were grown on 1% succinate to mid-logarithmic phase. Colicin E1 (1 μg/ml) was added 5 minutes before the initiation of anaerobiosis. Conditions otherwise as described in Fig. 1.*

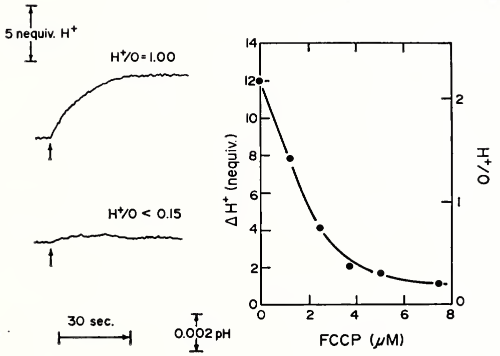
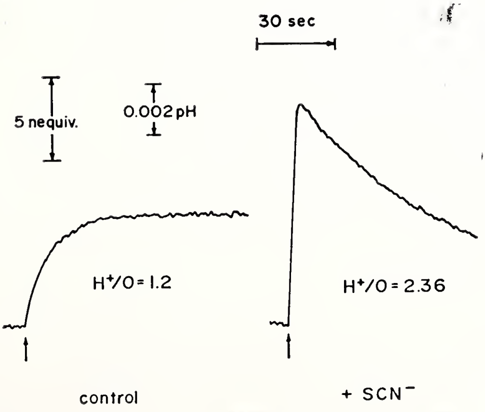


FIGURE 3. *Effect of the permeant anion* SCN^- *on proton efflux and the* H^+/O *ratio in* E. coli. *Cells of* E. coli *strain B/1,5 were grown on 1% succinate to stationary phase. Conditions otherwise as described in Fig. 1.*



logarithmic phase growth typically exhibit H+/O ratios of 0.5 or less, whereas succinate-grown cells harvested in stationary phase or glycerol-grown cells harvested in either log phase or stationary phase exhibit H+/O ratios around 1.0 (Fig. 1). In all cases the kinetics of proton efflux are rather slow ($t_{1/2} = 5\text{-}15$ sec). The pH change decays very slowly, with only a small fraction of the change reversed in 10 minutes. West and Mitchell (25) have previously observed similar small H+/O ratios for *E. coli* cells grown with glucose as carbon source and resuspended in a buffer-salts medium.

Treatment of the cells with colicin E1 before addition of the O_2 pulse results in a large change in the properties of the proton extrusion (Figure 1b). The rate of proton efflux is greatly stimulated, the pH change reaching a maximum ($\triangle H+$) in about 4-6 seconds. The halftime for the pH change ($t_{1/2} = 1$ sec) is very close to the half-response time of the electrode system determined by the addition of calibrated acid pulses to the medium. The rate of decay of the O_2-induced increase in medium acidity is also much faster after the cells have been treated with colicin E1 ($t_{1/2} = 10\text{-}20$ sec). The apparent H+/O ratio is increased to values > 2.0 after colicin addition, and this high H+/O ratio is no longer dependent upon either the growth phase of the cells or on the carbon source used for growth (Fig. 1). Furthermore, these effects of colicin E1 are only observed when colicin-sensitive cell strains are used (Table I). The H+/O ratios obtained with cells of the colicin-tolerant strain A_{586} and the colicinogenic strain JC411 are unaffected by 1 μg/ml colicin E1, whereas cells of the colicin sensitive strains B/1,5 and K12 1100 (cell survival $< 0.1\%$) show the effects described above and shown in Figure 1. Strain ML 308-225,

TABLE 1. *The effect of colicin El on proton extrusion (ΔH+)and the H+/O ratio in various* E. coli *strains.*

Cells were harvested from either mid-logarithmic phase growth (ML 308-225, K12 1100, B/1,5, A_{586}) or stationary phase growth (JC411). The carbon sources used for growth were 1% succinate (ML 308-225, K12 1100, B/1,5), 0.4% glucose (A_{586}) or 0.1% glucose (JC411). The concentration of colicin E1 was 1 μg/ml, which was sufficient to allow 0.1% survival of susceptible strains. The oxygen pulse contained 5.5 ng atoms O. Note that colicin does not cause any marked increase in the H+/O ratio in cells of the colicinogenic strain JC411 or the colicin tolerant strain A_{586}, and only a small effect in cells of strain ML 308-225, where survival was ~50% after treatment with 1 μg/ml E1.

E. coli strain	ΔH+ (nequiv.)		H+/O	
	−El	+El	−El	+El
A_{586} *(tol VIII)*	3.85	4.02	0.70	0.73
JC411 *(col E1)*	2.10	2.24	0.38	0.41
B/1, 5	2.30	12.20	0.42	2.22
K12 1100	5.25	12.90	0.95	2.35
ML 308-225	1.95	5.60	0.35	1.02

which is relatively insensitive to colicin E1 (survival = 50%) also showed an increase in the H+/O ratio in the presence of 1 μg/ml colicin E1, although the increase was not as large as that seen with the colicin sensitive strains and is predictable on the basis of a 50% survival level in this experiment.

The effects of the uncoupler FCCP on the oxygen-dependent proton pulse are very different from those described above for colicin E1. With concentrations of FCCP in the minimal range needed to inhibit active transport under aerobic conditions (2-5 μM) (21), the proton extrusion following an oxygen pulse is almost completely eliminated by FCCP in both normal cells and in cells treated with colicin E1 (Fig. 2). At concentrations of FCCP which give a partial inhibition of the extent of the proton extrusion, FCCP causes a marked increase in the decay of the pH change, due to the reentry of extruded protons into the cell (Table II). Thus, FCCP appears to act by increasing the permeability of the membrane to H+ ions—a conclusion consistent with much data already in the literature [e.g., ref. (32)]. Colicin E1, over a multiplicity range of 1-100 causes an increase in the extent of the

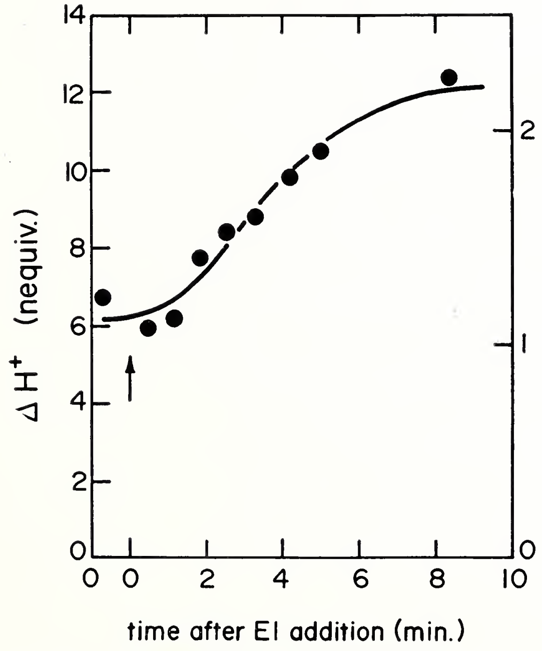


FIGURE 4. *(a) Time course of the increase in proton efflux* (ΔH+) *and the H+/O ratio by colicin E1. Cells of* E. coli *strain B/1,5 were grown on 1% glycerol to mid-logarithmic phase before harvesting. After the cell suspension had become anaerobic, colicin E1 was added (upward arrow) to a final concentration of 1 μg/ml. Oxygen pulses containing 5.5 ng atoms O per pulse were added at the indicated times after the addition of colicin E1.*

TABLE 2. *The effect of FCCP on proton efflux ($\Delta H+$), proton influx, and the H+/O ratio in colicin treated* E. coli

Cells of *E. coli* strain B/1,5 were grown on 1% succinate to mid-logarithmic phase before harvesting. The cells were treated with 1 μg/ml colicin E1 before the initiation of anaerobiosis. The indicated concentration of FCCP was added approximately one minute before the addition of any oxygen pulse containing 5.5 ng atoms O. Note that FCCP decreases the extent of the observed proton efflux while increasing the rate of subsequent proton influx.

FCCP (uM)	$\Delta H+$ (efflux) (nequiv.)	H+/O	$\Delta H+$ (influx) ($t_{1/2}$ in sec)
0	12.05	2.19	10
1.25	7.87	1.43	6.6
2.5	4.07	0.74	5
5.0	1.71	0.31	2

proton efflux even though it also causes an increase in the rate at which extruded protons reenter the cell (Fig. 1) (28). These findings are therefore consistent with the idea that colicin E1 causes an increase in the

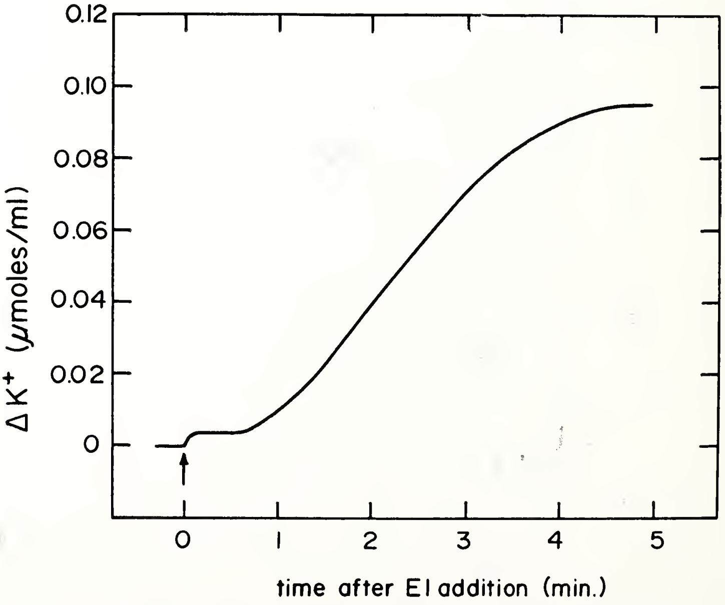


FIGURE 4. *(b) Time course of colicin E1-induced K+ efflux from* E. coli *cells. The cells were washed twice and resuspended in a medium containing 150 mM choline chloride, 0.5 mM MOPS- tris (hydroxymethyl)aminomethane (pH 7.0). Colicin E1 (dissolved in distilled H_2O) was added (upward arrow) to a final concentration of 1 μg/ml. No difference in the rate or extent of K+ efflux was observed between aerobic or anaerobic cell suspensions. Conditions otherwise described as in Fig. 1.*

permeability of the bacterial membranes to charge-compensating counter-ion(s). This notion is further supported by the finding that the effects of colicin E1 on the proton pulse can be mimicked by including the permeant anion SCN^- in the reaction medium. In the presence of SCN^- the kinetics of H^+ efflux, H^+ influx, and the H^+/O ratio are all increased (Fig. 3), much as they are in the presence of colicin E1 (Fig. 1).

Time Course of the Increase in H^+/O Ratio. The time-course for the colicin E1-induced increase in the H^+/O ratio for a suspension of cells grown in glycerol and resuspended in 150 mM KCl is shown in Figure 4a. The initial H^+/O ratio in the glycerol-grown cells is ~ 1.0 as in Fig. 1. After an initial lag of about 1 minute, the H^+/O ratio increases over a period of about 5-6 minutes ($t_{1/2} \sim 3$ min.) to a value approximately twice that measured before colicin addition. This time course is similar to that observed previously under anaerobic conditions for the colicin-induced change in the fluorescence intensity of the probe N-phenyl-1-naphthylamine (6). More importantly, the time course of the change in the H^+/O ratio is very similar to the time-course for K^+ efflux after colicin addition, measured under identical conditions (Fig. 4b).

Counterion requirement for the colicin E1 dependent increase in the H^+/O ratio. If the cells are treated with colicin in a choline chloride medium which is free of metal cations (K^+, Na^+, etc.) a similar time-course for the effects of colicin is observed, except (a) the H^+/O ratio prior to the addition of colicin is lower and (b) the H^+/O ratio does not attain the same high level (>2.0) seen in the KCl medium (Figure 5). Addition of KCl to a final concentration of 7.5 mM results in an immediate and abrupt increase in the H^+/O ratio to the maximum value observed in the KCl medium. This same effect of KCl is shown in a different way in Figure 6, where it is clear that in order to observe the effects of colicin E1 on the kinetics of proton efflux, proton influx, and on the H^+/O ratio, K^+ ion must be present in the medium. The smaller increases in the H^+/O ratio observed in Figures 5 and 6 before the addition of potassium can be attributed to the colicin E1-induced loss of K^+ from the cells (see below) which results in a final K^+ concentration in the medium of approximately 0.3-0.5 mM. This concentration of K^+ increases the H^+/O ratio to approximately one-half of the maximum value which can be obtained at higher external K^+ concentrations, indicating that the "K_m" for potassium required for colicin E1 effects is approximately 0.3-0.5 mM.

Discussion

The increase in H^+/O ratio caused by colicin E1 has been shown previously to occur at colicin multiplicities as low as one (28) and to require the presence of potassium ion. The time course for the increase in the H^+/O ratio ($t_{1/2} = 3$ min., Fig. 4a) is very similar to the time course for other early biochemical events initiated by colicin E1, such as the leakage of intracellular K^+ (Fig. 4b), the decrease in intracellular ATP levels, and the structural changes in the cell envelope

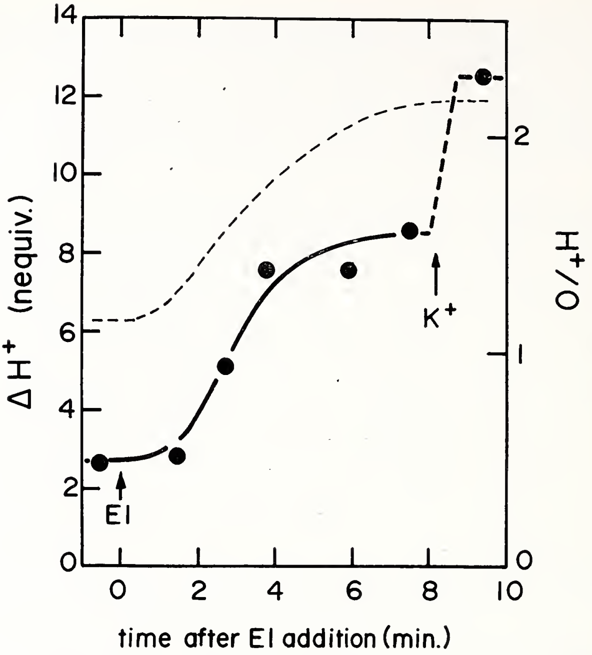


FIGURE 5. *Time-course of the increase in proton efflux ($\Delta H+$) and the $H+/O$ ratio in the absence of external $K+$ ions. Reaction conditions were as described in the legend to Figure 4b. After the cell suspension had become anaerobic, colicin E1 (dissolved in distilled water) was added to a final concentration of 1 μg/ml. Oxygen pulses containing 5.5 ngm atoms O were given at the indicated times. After the apparent $H+/O$ ratio had reached a maximum, about 8 minutes after the addition of E1, oxygen-free HCl was added in a small volume to give a final concentration of 7.5 mM. The thin dashed line (taken from Figure 4a) represents the time course and extent observed in the presence of 150 mM $K+$. Conditions otherwise as described in Fig. 1.*

monitored by fluorescence probes (6). In colicin-treated cells, the time-course of the change in H^+/O ratio (Fig. 4a), the dependence of the amplitude of the H^+/O ratio on externally added monovalent cations (Figs. 5, 6), and the similarity of the proton pulses obtained in the presence of colicin E1 to those obtained in the presence of SCN^- (Fig. 3) or valinomycin plus potassium (25), imply that the larger H^+/O ratios measured in these colicin-treated cells results from the fact that the efflux of H^+, which would normally generate a membrane electrical potential, can now be balanced by a counter flow of potassium or other ions. That is, the cell membrane seems to be freely permeable to potassium movement in either direction in the presence of colicin E1. We know little at this time about the mechanism of this increase in ionic conductance across the membrane, whether it is due to (a) an ionic channel created by the colicin itself or (b) induced in the inner

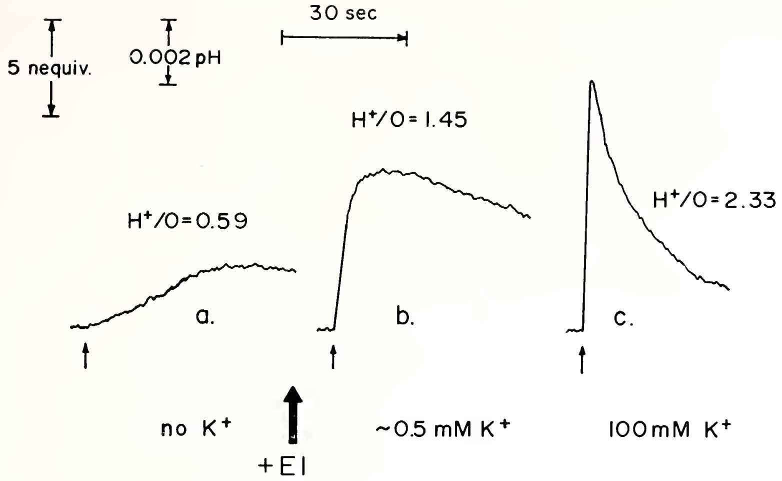


FIGURE 6. *K+ requirement for the increase in the rates of H+ efflux, H+ influx and in the H+/O ratio by colicin E1. Reaction conditions were as in Figure 5. (a) Control. (b) Cells were incubated for 8 minutes with 1 µg/ml colicin E1. (c) Same as b except 7.5 mM K+ was added prior to the oxygen pulse. Conditions otherwise as in Fig. 5.*

membrane through structural changes. While the former possibility seems somewhat easier to visualize, it has been inferred from experiments with colicin immobilized on sephadex beads that colicin E1 may not need to move from the neighborhood of its surface receptor in order to exert its effects (36). In any case, the consequence of free potassium movement and entry of other monovalent cations is that the cell should no longer be able to maintain a state of charge separation across the inner membrane. In other words, colicin E1, in the presence of potassium or other monovalent cations should cause a cellular membrane potential to be dissipated [but see (41)].

In previous work from this laboratory dealing with the mechanism of action of colicin E1 we have considered the nature of structural changes in the cell envelope (inner and outer membrane) associated with the primary process of membrane deenergization (37). This work has shown that deenergization of the cell by colicin E1, or by the uncoupler FCCP, causes a change in the rotational motion of the amphiphilic fluorescence probe ANS and the hydrophobic probe PhNap. An effective permeability barrier in the outer membrane to the hydrophobic probe is decreased upon deenergization of the envelope by colicin E1 and FCCP, resulting in some increased binding of the probe to the cells (21). The increase in the binding of PhNap after colicin treatment was first reported by Nivea-Gomez *et al.* (22) for cells treated with colicin Ia. The time course of these structural changes for colicin E1 (6) and colicin Ia (22) is very similar to that of the earliest biochemical changes, and raised the question as to whether such structural changes caused by colicin E1 could in fact be a primary event in the transmission of the lethal effect of this colicin (37). This hypothesis has the conceptual problem of explaining how a single protein added to the cell envelope can cause such an extensive structural change in the cell envelope. Degradative enzyme activity associated with early biochemical events following colicin E1 addition has not yet been detected (38). Since changes in the H^+/O ratio and dissipation of the membrane potential do occur as rapidly as the first detectable biochemical changes, it would seem that the structural changes and the change in the effective permeability barrier of the outer membrane could be an immediate consequence of the decrease in cytoplasmic membrane potential. One cannot specify at this time how a collapse in electrical potential across the inner membrane could cause immediate structural changes in the envelope other than to say that the local electric field density across the membrane is, of course, very high. There is precedent for electro-strictive effects on membranes (39), and it is clear from structural studies on the *E. coli* envelope that there are specific connections between the peptido-glycan layer and outer membrane (40).

There are a variety of other colicins which seem to have a mode of action similar to that of E1. These include colicin K, mentioned above, colicin Ia (42), colicin A (43, 44) and possibly S8 (45). Bacteriocins JF246 from *S. marcescens* and bacteriocin 1580 acting on gram-positive bacteria (44) also seem to resemble E1. These conclusions reached in this paper about the mode of action of E1 have been shown to apply to colicin K (28), and possibly apply as well to the above listed colicins and bacteriocins.

Acknowledgments

The authors would like to thank Ms. Julie Mukula and Ms. Suzanne Middendorf for capable technical assistance and Mrs. Mona Imler and Ms. Betty Gustin for typing the manuscript. Supported by NIH grant GM 18457 (W.A.C.) and by National Research Service Award (#1F32GM 00913) from the National Institute of General Medical Sciences to JMG.

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PHYSICS

Chairman: ROBERT E. HALE, Physics Department
Huntington College, Huntington, Indiana 46750

Chairman-Elect: ELMER NUSSBAUM, Physics Department
Taylor University, Upland, Indiana 46989

ABSTRACTS

The Whistler Phenomenon Used as a Tornado Warning Mechanism. GERALD J. SHEA, Indiana State University, Terre Haute, Indiana 47809.——For over sixty years scientists have investigated the whistler phenomenon. Discovered by accident during World War I it had to wait until the space age for a logical explanation. It is now believed the Van Allen belts trap energy released by thunderstorms to produce the phenomenon.

Whistlers may be detected by simple devices which can be built by anyone. A slightly modified audio amplifier provided with some form of antenna, a variable resistance coupled ground, and a recording instrument complete the apparatus.

Tornado-producing thunderstorms have been monitored on two occasions in 1976, one at 4:15 A.M. on February 21 and the other at 4:40 P.M. on March 20.

Results seem to show that whistlers increase in number as storm cells intensify. To observers in the path of the storm the phenomenon varies as to the approach and departure of the storm cell. However, only storms monitored at dawn and dusk so far have produced records of Whistler phenomenon. It remains obvious much more research remains to be done in this very interesting and relatively unexplored field of science.

Low Level Liquid Scintillation Spectroscopy. GREGORY PETERSON, Department of Physics, Indiana State University, Terre Haute, Indiana 47809.——A low level counting system is desired for alpha and beta emitting radionuclides solubilized in liquid scintillation fluid. A major problem in absolute counting of low energy radioisotopes (such as tritium or carbon 14) is that of energy quenching. Determination of quenching amounts of radioisotopes with liquid scintillation systems is laborious and time consuming. This paper reports on the modular interfacing of a liquid scintillation detecting system to a Northern ND180 multi-channel analyzer. The data from such a system shows that low level beta spectroscopy with energy quenched radionuclides is practical.

A Computer Based Comparison of Geometric and Analytical Algorithms for Elasticity Validity Testing of Stopping Kaon Beam Interactions with Free Protons in Nuclear Emulsion. P. MILLER and G. P. THOMAS, Ball State University.——A special computer program was devised to perform various operations on data collected from fifty-two suspected negative Kaon-Proton elastic interactions in nuclear emulsion. Collision fragment energies are interpolated from stored range-energy graphs. Then energies along with angle measurement data are used in the program to compute kinematical variables used in a comparison of geometric elasticity algorithms and more complete analytic elasticity algorithms.

Shadow Band, Radio Frequency and Optical Observations at the 23 October 1976 Solar Eclipse in Australia. MALCOM E. HULTS, DANIEL A. MITCHELL and DUANE W. WARN, Ball State University, Muncie, Indiana 47306.——Visual, photographic and photoelectric experimental systems to detect and measure shadow bands before and after totality were set up near the center line of the eclipse path north of Melbourne, Australia. Detectors to measure the predicted increase in rf noise during totality were also set up as well as equipment to photograph the corona of the sun.

Results are presented and compared with previous results from eclipses in 1966, 1970, 1972, and 1973.

PLANT TAXONOMY

Chairman: ORLAND J. BLANCHARD, Department of Biology
Earlham College, Richmond, Indiana 47374

Chairman-Elect: VICTOR RIEMANSCHNEIDER, Department of Biology
Indiana University-South Bend, South Bend, Indiana 46614

Pollination Biology of the Blue Mahoe, *Hibiscus elatus* Swartz (Malvaceae), in Jamaica. ANDREAS R. RICHTER and ORLAND J. BLANCHARD, JR., Department of Biology, Earlham College, Richmond, Indiana 47374. ——No detailed description of the pollination biology of *Hibiscus elatus* Swartz is known from the literature. In this study it was found that in *H. elatus* 1) flowers open just before sunset, 2) nectar flow is highest before 2000 hr., and ends by mid-morning the next day, 3) nectar sugar concentration levels drop from 12% at sunset to 5% at sunrise during the first night, 4) pollinated as well as unpollinated flowers are open for two days before dropping, but produce no nectar the second night or day, and 5) *Monophyllus redmani* (Chiroptera) is the effective pollinating agent. The original range of *H. elatus* in Jamaica and Cuba is wholly within the range of *M. redmani.*

The closely related *Hibiscus tiliaceus* Linnaeus, considered conspecific with *H. elatus* by some authors, is pollinated by insects (entomophily). The difference in pollination biology between *H. elatus* and *H. tiliaceus* may help to solve the taxonomic question of whether they are separate species or not. Moreover the few suspected cases of hybridization between the two *Hibiscus* may now be considered accidental, and not a regular occurrence.

Computerized Comparison of Parts of Fifty Herbaria. THEODORE J. CROVELLO, Biology Department, University of Notre Dame, Notre Dame, Indiana 46556.——A valuable byproduct of the use of computers in a monographic study of *Cardamine* (including *Dentaria*) and *Streptanthus* (Brassicaceae) is information about the collections of the more than fifty herbaria and museums from which 45,000 specimens were borrowed. At least for these genera, involving close to 100 species, accurate estimates of their representation in herbaria now can be made. These genera were particularly suitable for such an analysis because they include both widespread species and very confined endemics; because they include xeric and mesic taxa; and because they include weeds and nonweeds. Questions of particular interest that are now answered include: How regional are the holdings of a given herbarium? If I study specimens from the largest five or ten herbaria, how many additional county records, over time, will I find by studying the next largest five or ten? This study is believed to be the first large monograph to capture data from many herbaria by computer.

Cytology, Hybridization and Evolution in *Kosteletzkya* (Malvaceae). ORLAND J. BLANCHARD JR., Department of Biology, Earlham College, Richmond, Indiana 47374.——*Kosteletzkya* is a genus of about fourteen species centered mainly in Africa and the circum-Caribbean region. Seven species, *K. buettneri* and *K. adoensis* from Africa, and *K. virginica, K. paniculata, K. pentasperma, K. coulteri* and *K.* sp. nov. from the New World, have been grown in the greenhouse. All have haploid chromosome numbers of $n = 19$. Experimental cross pollinations have produced fifteen of the 21 possible hybrid combinations among these seven species. Pollen stainability and fertility of hybrids suggest a strong affinity among the New World species and a less strong an affinity of these species with the African *K. buettneri.* The two African species fail to cross with one another, and *K. adoensis* only crosses with *K. pentasperma.* All New World hybrids show nearly normal meiotic metaphase I (average number of bivalents is 18.2-19.0), and all crosses with *K. buettneri* likewise have near normal meiosis (18.9-19.0). The *K. adoensis-K. pentasperma* hybrid, on the other hand, shows very poor pairing (1.1 bivalents). The existence of two clearly differentiated genomes in Africa, one of which is shared with the New World species, suggests that the African species have experienced a longer evolutionary history. This interpretation is supported by the fact that these and other major African species are largely sympatric while the New World ones are almost entirely allopatric.

Changes in Indiana's Vascular Flora Since 1940. CLIFTON KELLER, University of Notre Dame, Notre Dame, Indiana 46556, and Andrews University, Berrien Springs, Michigan 49104.——Charles Deam summarized the known distribution of each of the 2243 vascular plant species in his 1940 *Flora of Indiana.* Since then, 8000 new county records have been added. Deam's data base was compared with the additions. It appears that: 1) the new records conform to previously established floristic patterns; 2) collection intensity over the state has not been uniform; 3) a considerable amount of collection still needs to be done in Indiana if administrators are to make intelligent environmental decisions. Mark sense cards designed to accumulate information from herbarium specimens or from personal collections were described. These would provide an economical way to bring new specimens of potential importance to the attention of the scientific community.

A New Leaf Mutation in Black Walnut (*Junglans nigra* L.)

STEPHEN G. PENNINGTON, State Tree Improvement Forester
Indiana Division of Forestry, Vallonia, Indiana 47281

WALTER F. BEINEKE, Department of Forestry and Natural Resources
Purdue University, West Lafayette, Indiana 47907

Abstract

A new leaf mutation in black walnut (*Juglans nigra* L.) has been discovered. The new form has a large, round terminal leaflet with 2-4 very small lateral leaflets. Seedlings with the new form were produced by one parent tree and 19 percent of the seedlings from that tree have the peculiar form. The remainder of seedlings from that parent have normal leaves.

The cause is suspected to be a single-gene recessive mutation. Studies are planned to determine the exact genetic cause.

A new mutation in black walnut (*Junglans nigra* L.) has been found (Fig. 1). The new form is unique, has not been reported before, and differs from the normal black walnut in the following characteristics:

1. The new leaf form has a large round terminal leaflet (approximately 7.0 cm diameter) with an indented apex and 2, 3, or 4 very small lateral leaflets (approximately 2.5 x 2.0 cm) (Fig. 2). The normal black walnut leaf has 9-23 lanceolate leaflets approximately 10 cm x 4 cm.

2. Total leaf length of the new type was approximately 12.5 cm while the normal is approximately 50 cm (Fig. 2).

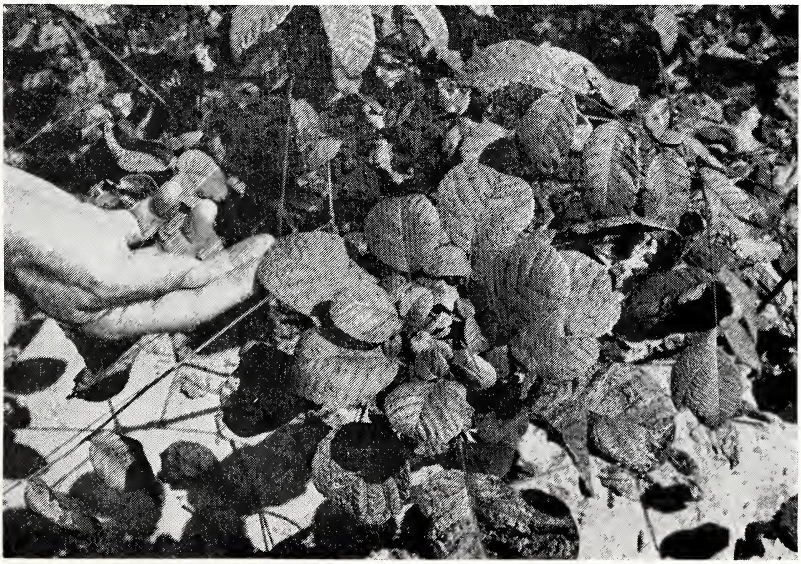

FIGURE 1. *Mutated leaves of black walnut in the nursery bed at Vallonia State Tree Nursery.*

3. In some mutated leaves the first lateral leaflet is fused to the terminal leaflet giving a lobed appearance.

4. The buds of the mutant were smaller and more rounded than a typical bud. This is probably due to the small leaf size of the new type.

5. First year height of the mutated seedlings averaged 27.4 percent taller than normal seedlings in the same family (seed collected from one parent tree) (Table 1). However, when compared to seedlings from the other sources, this family was shorter than average. Thus, even the taller mutated seedlings were not superior in growth to other sources.

6. The mutated seedlings appeared to be very susceptible to anthracnose (*Gnomonia leptostyla* Fr.) which caused defoliation to begin in mid-August. Seedlings were essentially leafless by September 7, 1976.

The only similar mutations reported in the literature involved California black walnut (*Juglans californica* S. Wats.) and Hinds walnut (*Junglans hindsii* Jeps.) (1). Researchers have no reports of similar mutations in *Junglans nigra.*[1]

This mutation was found in the course of the annual progeny testing phase of the genetic improvement program for black walnut conducted by the Indiana Division of Forestry and Purdue University. Progeny tests annually consist of 1000 to 4000 seedlings from approximately 80 different parent trees. The tests are planted in a randomized complete block design using five replications. The mutated seedlings were observed in the 1976 progeny test in the nursery beds. Nineteen

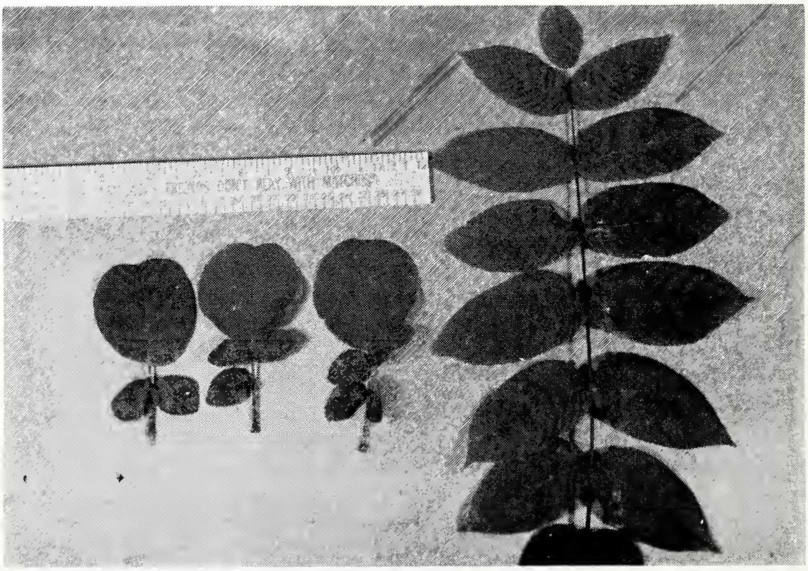

FIGURE 2. *Mutated leaves on the left versus a normal leaf from a seedling in the same family on the right.*

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[1] Personal communication—Dr. David Funk, U.S. Forest Service, Carbondale, Illinois 62901.

TABLE 1. *Height growth of mutated vs. normal black walnut seedlings in family 143.*

Block	Mean Height Normal Seedlings (cm)	Mean Height Mutated Seedlings (cm)	Height Increase of Mutated Over Normal (%)
1	24.9	28.5	14.5
2	23.6	35.2	49.2
3	26.0	32.3	24.2
4	26.7	33.7	26.2
5	22.9	28.3	23.6
Mean	24.8	31.6	27.4

percent of the seedlings from a single family showed the new leaf trait (Table 2). The remainer of the seedlings from that family were normal.

Speculation as to the genetic origin of the new type has centered on a single gene recessive trait in the parent tree. Two possible explanations for the ratio of mutated to normal plants have been considered: 1) The mutated seedlings could be the result of self-pollination in the heterozygous parent tree. Black walnut is known to self pollinate provided weather conditions are favorable and dichogamy is lacking (2). 2) Another tree in the vicinity of the parent tree may also be heterozygous for the mutation (sib or progeny) and has cross pollinated to produce the nearly 3:1 ratio.

Inspection of the parent tree and neighboring trees in northern Indiana, and grafts from the parent tree in the clone banks at Purdue University-Martell Forest show no indications of the mutation (3).

This discovery may prove to be extremely important in the breeding of black walnut in that for some studies a "marker gene" is required. This mutation is readily identifiable, occurs in one-year-old seedlings, and unlike most chlorophyll deficiencies is not fatal, thus making it an ideal marker gene in selfing, and controlled pollination studies.

Future tests to define the real genetic causes include grafting of scions to mature walnut trees for future controlled pollination studies, seed collection from trees in the vicinity of the parent tree, and observation of flowering times in the parent and surrounding walnut trees.

TABLE 2. *Occurrence of leaf mutations in family 143 in a black walnut progeny test.*

Block	Seed Planted (No.)	Total Seedlings (No.)	Mutated Seedlings (No.)	Mutated Seedlings (%)	Germination (%)
1	40	23	4	17	58
2	40	34	7	21	85
3	40	11	4	36	28
4	40	29	3	10	73
5	40	31	6	19	78
Mean & Totals	200	128	24	19	64

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SCIENCE EDUCATION

Chairman: HAROLD H. JAUS, Department of Education
Purdue University, Lafayette, Indiana 47907

Chairman-Elect: JON R. HENDRIX, Department of Biology
Ball State University, Muncie, Indiana 47306

ABSTRACTS

Myths about Human Inheritance That Are Perpetuated in the Biology Classroom Laboratory. THOMAS R. MERTENS and PATRICIA S. BARNES, Ball State University, Muncie, Indiana 47306.——Twenty-six selected introductory biology and genetics laboratory manuals were examined and were found to include 57 human "inherited" traits as examples for classroom study. Forty-three of these 57 traits are included in McKusick's catalog of human inherited characteristics, *Mendelian Inheritance in Man* (1975). Of these 43 traits, 26 are annotated to indicate that their modes of inheritance are well documented, while 17 traits are not so annotated, suggesting uncertain mechanisms of inheritance. Fourteen of the 57 traits are not found in McKusick's catalog, implying that they may not be inherited traits or that their modes of inheritance may be polygenic.

Current literature also suggests that certain traits included in the McKusick catalog may not, in fact, have a genetic basis. Notable examples of such questionable traits are handedness, hand clasping, and tongue rolling.

Clearly, a need exists for reliable morphological and easily detected biochemical human genetic traits for use in classroom instruction. Authors preparing instructional manuals for introductory classroom laboratory studies should carefully select the traits with which they illustrate human inheritance. A first requisite for selection must be conclusive evidence that the trait does, indeed, have an established genetic basis.

Changing Elementary Teachers' Attitudes toward Environmental Education. HAROLD H. JAUS, Purdue University, West Lafayette, Indiana 47907.——The purpose of this investigation was to determine the effects of environmental education instruction on the attitudes of inservice elementary teachers toward environmental education. Two groups of elementary teachers were randomly assigned to two graduate level science methods classes. Both groups were provided the same science methods instruction via self-instructional handouts. Upon completion of this instruction, the experimental group ($n = 26$) received content and methodology training in environmental education. The topics covered in this environmental education instruction included: ecology, pollution, overpopulation, resource allocation and depletion, conservation, and urban and rural planning. The control group ($n = 25$) did not receive this environmental education instruction, but carried out activities from the various national science curricula.

Following treatment, both groups were given an instrument designed to measure their attitudes toward teaching environmental education in the elementary classroom. This attitude measure consisted of 30 statements which the subjects responded to on a Likert-type scale consisting of five categories. The reliability of the measure was determined on a test-retest basis using a group of teachers not involved in the study. The resultant reliability value was .86.

A t-test for independent samples was used to analyze the scores of the attitude measure. The mean score difference between the two groups was 40.16. The resultant t-value of 9.25 with 49 degrees of freedom was significant at the .001 level.

Based on the results of this study, it would appear that elementary teachers who have received instruction in environmental education have significantly more positive attitudes toward teaching environmental education in their classrooms than teachers who have not received this instruction.

A Survey of Bioethics Courses in United States Colleges and Universities. JON R. HENDRIX, Ball State University, Muncie, Indiana 47306.——In order to facilitate the development of a meaningful bioethics course for Ball State University students, a survey instrument designed to ascertain the nature and number of bioethics courses currently taught in major United States universities and colleges was developed and sent to 360 colleges and/or universities. The *1974-75 Educational Directory of Higher Education* was used to identify every college and university in the United States that had an enrollment of 5,000 or more students and offered a minimum of a baccalaureate degree. Two hundred twenty-three returns (62%) were received and tallied. The data collected in this survey indicate that 26% of 223 responding colleges or universities have a bioethics course. The biology department most frequently houses the bioethics course; however, many other disciplinary as well as interdisciplinary departments also house the course. Medical-paramedical students are the most frequent majors taking bioethics courses in 36% of the reporting institutions; they are closely followed by humanities majors, 26% of the reporting institutions and non-teaching biology majors, 26% of the reporting institutions. Few, 9%, of the institutions reported that bioethics courses consisted largely of biology teaching majors. The teachers of bioethics courses most frequently have either a bioethics or ethics/philosophy background. A variety of teaching methodologies is used in bioethics courses. The most frequently employed methods were lecture and readings with reports. Consensus was reached on three major goals of bioethics courses; however, no consensus was noted on the curricular materials used to teach a bioethics course.

Increasing High School Biology Achievement by Differentially Sequenced Instructional Materials. CLAUDIA B. DOUGLASS, Central Michigan University, Mount Pleasant, Michigan 48859.——The primary purpose of this research was to identify a possible interaction between the cognitive style of the students and the instructional sequence of the materials.

The students were ranked and classified according to cognitive style on the basis of their performance on the Group Embedded Figures

Test. They were then assigned to one of three treatment groups. Two treatment groups were experimental groups following carefully sequenced sets of biology materials on the topics of genetics and probability; while the third group served as a control group following a set of related units. The instructional materials for all students were of an audio-tutorial, self-paced, mastery format. A comprehensive posttest measured achievement, and a measure of general intelligence was obtained for all students to be used as a covariant. This pretest-posttest control group design was conducted in the biology classes of six midwestern high schools.

Two levels of cognitive style (field-dependence and field-independence) and three levels of instructional materials (deductive, inductive, and control) were combined factorially in a 2x3 design. Descriptive statistics and correlation coefficients were calculated to provide an overview of the data. Two-way analysis of variance and covariance were performed to investigate all possible main effects and interactions. A stepwise multiple regression was performed to determine the predictive powers of IQ and field-dependence-independence on the dependent measure of genetics and probability achievement.

The major conclusion of the study was the cognitive style and instructional sequence interacted in such a way that the field-independent subjects experienced a higher level of achievement with inductively-sequenced materials and the field-dependent subjects experienced a higher level of success with deductively-sequenced materials.

Contractual Learning: A Viable Approach to Education in the Sciences. GEORGE A. ASTERIADIS, Purdue University-North Central Campus, Westville, Indiana 46391.——The traditional role of the educator has been that of an authoritarian who dictates to, rather than guides, his students. I believe an educator can better serve his students by adopting the role of a facilitator. A climate of mutual respect and trust should be established allowing both the student and educator to accept their respective responsibilities in the educational process. The student should be given the responsibility to develop and complete his educational goals and objectives, and thus the opportunity to achieve a personally meaningful education. The educator should attempt to understand and accept his students, become a flexible resource willing to share his views rather than dictating his opinions, and assume the role of a co-learner.

When an educator adopts the role of a facilitator, then consideration of the concepts of individualization within the learning process becomes necessary. I have chosen the concept of contractual learning as a means of individualization. This educational alternative requires the student to develop a three part contract which contains:

(1) his learning goal(s)—a statement of the overall learning experience(s) to be obtained from the course,
(2) his learning objectives—a statement of how the student is to accomplish his goal(s) (specific activities, types of resources to be used, etc.), and
(3) the criteria and procedures to be used in evaluating the level of performance on each objective must be specified.

This alternative can be used in situations where you want to facilitate students' total freedom in the learning process (e.g., elective courses, seminars) or, be somewhat modified for use in required courses where exams are considered necessary by the instructor.

Seminar Procedures for High School Advanced Biology Classes. PATRICIA ZECK, Northwestern High School, Kokomo, Indiana 46901.——As a bridge between ecology and genetics units in her advanced biology classes, the author invited her students to participate in any subdivisional topic of ecology and genetics. Each group of 3-6 students plans over 2-3 weeks a seminar to last 2 or 3 days. Library research, group conferences, ordering supplies, and inviting speakers are preliminary tasks. Sample seminar activities are field trips, skits, dances, guest speakers, movies, video tapes, songs, games, and worksheet handouts. After all groups are done, oral and written evaluations are made by the students. Teacher evaluation is based on knowledge of subject, variety of media used, preliminary agenda, originality, time budget, overall effectiveness, and amenities.

The Basics of Elementary School Science. H. MARVIN BRATT, The Ohio State University, Marion, Ohio 43302.——In October, 1974, Newsweek magazine carried a rather incisive article which compared two schools in Pasadena, California. The title of the article was "Back to Basics in the Schools." Since then, all one hears at school board meetings, teachers' meetings and the P.T.A. is "Let's get back to basics." The first question one might ask is "What are the basics?"

In this paper I should like to describe what might be called "the basics" for children of elementary school age in terms of science education. An examination of the basics should include some discussion of the content of science, the process or method of science, and certain skills which should be developed in young children as they prepare for additional educational experiences and for life itself.

Some educators behind the back to basics movement feel that reading, writing, and arithmetic should be the only subjects taught in the elementary school. I believe that if the truth were known, schools are spending more money on these three subjects than anything else except law enforcement and school busses. The suggestion is, therefore, that we not forget what we have learned during the past several years, but review it thoroughly. In addition, it would help if students would learn basic thinking skills which seem to be lacking upon graduation from school.

How to Individualize Your Science Class by Developing Folder Carrels. STANLEY S. SHIMER, Indiana State University, Terre Haute, Indiana 47809.——A folder carrel is an activity, skill or game that can be put into a manila folder so that the student can read the directions for performing the tasks, checking his answers, returning carrel to its original condition and place, and completing follow-up assignments. The advantage of the folder carrels is that they provide immediate feedback to students, can be interesting and fun, and are easy to store when space is at a premium.

The proposed items and procedures have evolved over the past seven years as a result of working with university students and in-service teachers as they developed carrels for their classes. For student use the four indicated items are all that are needed. However, when a teacher plans a folder carrel or when a fellow teacher wishes to use or duplicate a carrel, additional information is required. Before developing and/or duplicating folder carrels, the teacher must make decisions regarding the subject area (life, physical or earth); classification (skill, activity or game); grade level range; concept or performance objective; specific outcomes expected; title; materials needed; procedures; and sources.

Creative teachers can select materials for the folder carrels that are attractive and challenging; thus, folder carrels are excellent self-contained teaching aids.

Helping to Conceptualize Large Numbers. FREDERICK K. AULT, Ball State University, Muncie, Indiana 47306.——Using numbers for describing chemical phenomena is an extremely frustrating experience for many students taking introductory chemistry courses. Numbers such as the mole (6.02×10^{23}), Planck's constant (6.6×10^{-27} erg•sec), and the speed of light (3×10^{10} cm/sec) are typical of numbers used in chemical communication. These numbers represent quantities well beyond our experience and consequently are highly abstract. These numbers become more abstract when used in conjunction with other measurement units.

Appropriate analogies with demonstrations have been used effectively in the classroom for treating chemical concepts involving numerical components. A demonstration involving an analogy for treating the mole concept was presented. Other analogies were suggested.

Farm Equipment Use Costs. JAMES MITCHELL SMITH, New Castle Area Vocational School, New Castle, Indiana 47362.——To establish significant figures for several farm operations, this writer developed work sheets which are used with "Purdue University Bulletin EC-130 (Rev) Indiana Custom Rates for power operated farm machines 1974."

Adult men, all military veterans, take part in vocational classes in agriculture in this Vocational School. The educational background of these men vary and projects relating to them must give immediate results which are easily understood.

Class discussion of each phase of the operation was encouraged. Several men developed the project on the basis of least cost, others determined time needed for each operation as well as cost. Several men questioned older practices with numerous trips across a field and use of many different kinds of equipment. As a result of these sheets, students examined the estimated cost of crop production relation to return from the crop.

The sheets can be used in their present form for any part of Indiana. The sheets together with EC-130 (Rev) may serve as a format for expansion of other existing bulletins and existing resource material and their adaption for specific uses.

SOIL AND ATMOSPHERIC SCIENCES

Chairman: HARRY M. GALLOWAY, Department of Agronomy
Purdue University, Lafayette, Indiana 47907

Chairman-Elect: LAWRENCE A. SCHAAL, Department of Agronomy
Purdue University, Lafayette, Indiana 47907

ABSTRACTS

An Agroclimatological Grid System: A Preliminary Report. J. M. DAVIS, Indiana University, Bloomington, Indiana 47401.——Significant advances have been made in modeling the physiological aspects of plant growth and the plant's microclimatological environment. To make operational use of these models on a day-to-day areal basis, microclimatological data must be collected and processed more efficiently. To that end, this paper describes the establishment of an 800-point agroclimatological grid data system for the southeastern United States. Grid point data consists of two main types: that data which is collected each day (e.g., air and soil temperatures, rainfall, soil moisture, etc.) and data that generally remains constant over time (e.g., grid point climatological data, soil horizon data, "major crop" grid data, etc.). A 3-D grid array is needed for some data sets. The grid is resolved by means of a variational analysis method. Analysis of the observed rainfall and temperature data is compared with the analysis of the grid data generated by the variational analysis procedure. Flow charts are provided which show how a complete system of plant models, microclimatological models, and grid data could be organized for efficient operational use. Consideration is also given to problems associated with areally sparse data.

Regionalizing Purdue's Soil Testing Procedures. RUSSELL K. STIVERS, Department of Agronomy, Purdue University, West Lafayette, Indiana 47907.——Recommended chemical soil testing procedures for phosphorus and for potassium for the North Central Region were compared to Purdue procedures for these plant nutrients. Soils were weighed rather than scooped in all experiments. In two experiments, each with six different soils and three replications per soil, there were no significant (probability $< .05$) differences in phosphorus test values between the Purdue procedure for Bray-1 phosphorus and the Regional procedure, both of which used aminonaphthol-sulfonic acid, sodium sufite, and sodium pyrosulfite in the reducing agent to develop the ammonium phosphomolybdate blue color. The main differences were in volumes and concentrations of reagents used in color development, resulting in different standard curves for percent light transmittance (660nm) versus concentration of phosphorus. The neutral normal ammonium acetate procedures used both by Purdue and by the Region to extract soil potassium differed from each other in (a) soil to extracting solution ratio, (b) in length of shaking time, and (c) in type of extraction vessel. These differences were made the basis for four treatments each with three replications in two different experiments, one with six soils and one with eight other soils. These treatments resulted in significantly different soil test values for potassium with only one of the six silt loam or heavier soils, in none of the four sands or loams, and in three of the four organic soils.

Have the Mississinewa and Salamonie Reservoirs Changed the Climate at Marion and Huntington, Indiana? ROBERT F. DALE and PATRICK R. CLARE, Department of Agronomy, Purdue University, West Lafayette, Indiana 47907.——The effect of the Mississinewa and Salamonie reservoirs on modifying air temperatures at Huntington and Marion, Indiana, is small. Since these mesoclimatic anomalies are likely to be smaller than those induced by any changes in weather station location, instruments, or time of observation, it is mandatory that only homogeneous station records be used to identify reservoir effects. Under prevailing southwesterly flow, there is some evidence that the August daily mean maximum temperatures at Huntington, 13 km "downwind" from the Salamonie Reservoir, were decreased about 0.5°F by the reservoirs. Two techniques were used to investigate the temperature change, and recommendations are made for future work.

Soil Aggregates ($> 210\ \mu$) Transported in Runoff from Northeastern Indiana Cropland. S. A. SCHROEDER, J. V. MANNERING, C. B. JOHNSON, Purdue University, West Lafayette, Indiana 47401.——To determine the percentage of soil loss as aggregates larger than 210 microns, samples of runoff were taken throughout three simulated rainfall tests on four soil types. The soils used were level Hoytville silty clay loam, Nappanee loam, and Haskins loam and gently sloping Morley loam. Work was conducted in the Black Creek Study Area of the Maumee basin in Allen County, Indiana.

Values ranged from approximately 3% to 29% depending upon the treatment and soil under consideration. It was concluded that the low velocity of runoff was the limiting factor in the transport of aggregates larger than 210 microns on the three soils with level ($< 2\%$) slopes. On the Morley soil (4% slope) the factor limiting soil loss in aggregate form appeared to be the poor structure of the soil *in situ.*

Therefore, these results indicated that effective measures for reducing erosion of aggregates larger than 210 microns on nearly level slopes must be based on prevention of detachment and dispersion of naturally-occurring aggregates by raindrop impact rather than on control measures designed to reduce runoff velocity.

Additional key words: erosion, aggregates.

Use of LANDSAT Imagery as a Base Map for Making a General Soils Map. KARL H. LANGLOIS, JR., United States Department of Agriculture, Soil Conservation Service, Monticello, Indiana 47960, LARRY C. OSTERHOLZ, Indiana Department of Natural Resources, Monticello, Indiana 47960 and FRANK R. KIRSCHNER, Laboratory for Applications of Remote Sensing, Purdue University, West Lafayette, Indiana 47907.——General soil maps provide important resource data for a wide range of uses. Previously, detailed soil maps were used with a county road map as a base map to develop a general soil map. In White County, Indiana, LANDSAT imagery was used as a base map. LANDSAT imagery shows, in color, many patterns that depict soil landscape units. A major benefit of LANDSAT imagery is that it permits an evaluation of the soil landscape independent of the soil maps. Use of LANDSAT imagery also improves the accuracy of placing boundaries on a general soil map, and the ease in which it is made.

Mapping Unit Composition as Defined by Digital Analyses of LANDSAT Multispectral Data. FRANK R. KIRSCHNER, SUE A. KAMINSKY, and DONNA K. SCHOLZ, Laboratory for Applications of Remote Sensing, Purdue University, West Lafayette, Indiana 47906.——Multispectral data obtained from LANDSAT and analyzed by digital computer was used to develop a classification (soils map) of a four-square-mile area of Clinton County, Indiana. Using spectral data, three distinctly different soil mapping units were investigated to determine the nature and extent of the inclusions in each. Fifteen spectrally different patterns were recognized based on their spectral response statistics. These spectral classes were placed into four soil groups and one vegetative group based upon the magnitude of their reflectance and the ratio between the visible and near infrared reflectance. The four soils groups can be related to four distinct soil drainage classes. These classes were used to characterize the inclusions within the mapping units. Results indicate that the composition of the soil mapping units can be quantified and characterized using multispectral digital data.

Inventory of a Nature Preserve Area in Lake County, Indiana Using Satellite MSS Data[1]

S. J. Kristof, F. R. Kirschner, R. A. Weismiller, and S. A. Kaminsky[2]
Laboratory for Applications of Remote Sensing, Purdue University

Abstract

Computer-aided techniques were used to classify Landsat data in order to distinguish terrestrial features within the Hoosier Prairie tract near the city of Griffith, Lake County, Indiana. Data within the study area were divided into distinct spectral classes by a clustering procedure. A statistics algorithm was used to compute the mean and covariance for each cluster class. Terrestrial ecosystems were classified using a maximum likelihood algorithm. The output consisted of a spectral map with each class represented by a different alphanumeric symbol. The descriptions of the spectral classes were based upon their mean vector ratios and data collected at the ground site.

Computer-aided analysis of Landsat data was successful in distinguishing eight informational classes within the highly complex plant regime of the Hoosier Prairie Nature Preserve Area.

Introduction

The objective of this research was to investigate the application of computer-implemented analysis (2, 5) of Landsat data to recognize major vegetative cover and important physiognomic characteristics of species in a 121 hectare area of Lake County, Indiana. This area is characterized by a mixture of wetland prairie, dry prairie and oak savannas with over 300 different plant species (4).

Description of the Area

The study area, known as the Hoosier Prairie Nature Preserve, is a part of the remaining prairie in the northwestern part of Lake County, Indiana. It is situated in the former glacial Lake Chicago and the soil parent materials are primarily glacial till, lacustrine deposits, beach sands and gravels. Most of the soils are poorly drained with a relatively high water table such as Maumee fine sand or moderately well drained such as Brems fine sand. There are also some excessively drained soils such as the Plainfield fine sand with 0 to 6 slopes.

Data Analysis Procedure

September 7, 1975 Landsat multispectral scanner (MSS) data obtained over the Hoosier Prairie tract located in the Griffith-Highland-Schererville area was used for analysis.

A nonsupervised clustering algorithm was used to analyze and group individual remote sensing units or pixels into clusters of similar

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[2] Research Agronomist, Agronomy Department; Soil Scientist, USDA/Soil Conservation Service; Research Agronomist, Agronomy Department; Graduate Student, Agronomy Department, respectively. Purdue University/Laboratory for Applications of Remote Sensing.

spectral response. Although the Hoosier Prairie tract consists of only 121 hectares, a much larger area, 2172 hectares, was used for clustering to increase the spectral contrast so as to represent adequately all of the spectrally distinct features in the Hoosier Prairie tract. A statistics processor calculated the mean vector and covariance matrices for each cluster class in each of four wavelength bands. Using the statistics developed, a nonsupervised maximum likelihood classification algorithm was used to classify the area into 17 spectrally separable classes. Cover types were identified using a mean vector ratioing technique. This is a heuristic ratio:

$$A = \frac{V}{IR}$$

where V is the relative intensity of the visible wavelengths [(0.5 to 0.6μm) + (0.6 to 0.7μm)] and IR is the relative intensity of the reflective infrared wavelengths [(0.7 to 0.8μm) + (0.8 to 1.1μm)].

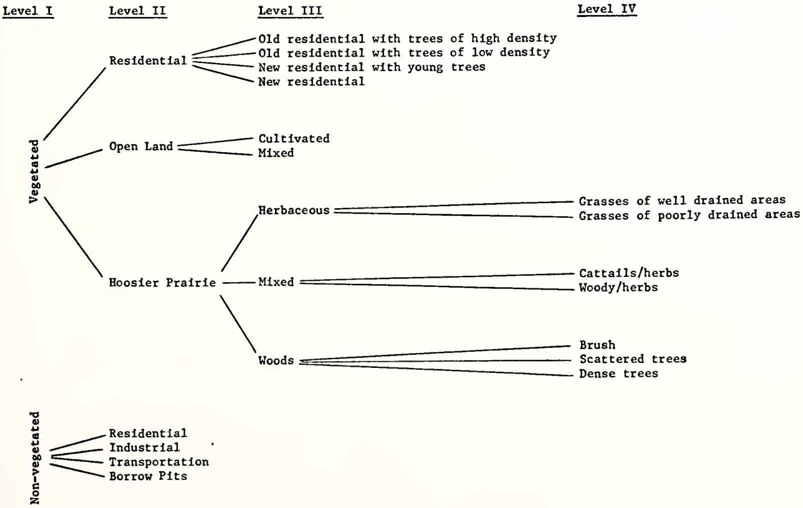
By summing the relative intensity values of all four bands the magnitude of relative spectral responses can be obtained as shown in the following equation:

$$\text{Summed response} = (0.50 \text{ to } 0.60\mu m) + (0.60 \text{ to } 0.70\mu m) + (0.70 \text{ to } 0.80\mu m) + (0.80 \text{ to } 1.10\mu m).$$

By observing the ratio A and the summed response, the analyst delineated major vegetation and land use categories within the Hoosier Prairie tract. Topographic, soil survey and geologic maps, aerial photography and limited ground observations also aided in determining the associations existing between spectral classes and ground features.

A hierarchical land use classification scheme similar to that developed by the U.S. Geological Survey (1) was followed (Table 1). Two broad

Table 1. Classification Hierarchy



Level I	Level II	Level III	Level IV
Vegetated	Residential	Old residential with trees of high density	
		Old residential with trees of low density	
		New residential with young trees	
		New residential	
	Open Land	Cultivated	
		Mixed	
	Hoosier Prairie	Herbaceous	Grasses of well drained areas
			Grasses of poorly drained areas
		Mixed	Cattails/herbs
			Woody/herbs
		Woods	Brush
			Scattered trees
			Dense trees
Non-vegetated	Residential		
	Industrial		
	Transportation		
	Borrow Pits		

TABLE 1. *Classification Hierarchy.*

Level I categories, vegetated and nonvegetated, were separated solely on the basis of their spectral responses. The mean vector ratios of the vegetated and non-vegetated areas were 1.00 or less and 1.10 to 1.30, respectively. The mean vector ratio statistics in conjunction with conventional photointerpretation of aerial photography were used to determine the Level II categories. At this stage the vegetated category was divided into vegetated residential, open land and Hoosier Prairie while the non-vegetated category was split into non-vegetated residential, industrial, and borrow pits.

Ground observations were used to further differentiate the Hoosier Prairie area into the Level III land cover categories of (a) herbaceous, (b) mixed herbaceous with woody plants and (c) woods and Level IV categories of (a) grasses on well drained areas, (b) grasses on poorly drained areas, (c) marsh-cattails and herbs, (d) marsh-shrubs and herbs, (e) brush, (f) scattered trees, (g) dense trees and (h) other.

Results and Discussion

The main effort of this study involved an assessment of the utility of the Landsat data to detect, identify, locate and measure features of the area of approximately 121 hectares known as the Hoosier Prairie Nature Preserve which has remained relatively undisturbed. Because of the complexity of the location and in order to obtain greater spectral contrast within the area the investigation was expanded to include the metropolitan area of Griffith and open land to the north and cultivated land to the west of the Hoosier Prairie.

Within the entire study area two broad classes, vegetated and non-vegetated, were classified, their identification based upon their mean vector ratios. Non-vegetated terrestrial features exhibited high ratios due to high responses in the visible and much lower responses in the reflective infrared portion of the spectrum. Green vegetation exhibited lower ratio values due to high responses in the reflective infrared and low responses in the visible region of the spectrum.

Since the vegetative cover of the Hoosier Prairie represents a highly complex regime of native herbaceous, annual and perennial plants situated in colonies many times smaller than 0.5 hectare, the spectral resolution of Landsat, it is readily apparent that it would not be possible to delineate individual plant species using Landsat data. However, it was possible to classify the Hoosier Prairie area into 9 spectrally separable classes (Figure 1). These classes were separable due to differences in the type of vegetative cover, the density of vegetation and the wetness in the terrestrial ecosystems. By comparing the spectral classification to aerial photographs and field observations these nine spectral classes were interpreted to represent eight informational classes (Table 2). Figure 2 shows the relative spectral responses of the seven vegetative covers identified within the Hoosier Prairie tract. As the density of the vegetation increases (i.e., scattered trees vs. dense trees) the ratios decrease in value. Also it can be shown that vegetation on wet terrestrial ecosystems exhibit lower relative magnitude values than vegetation on dry ecosystems.

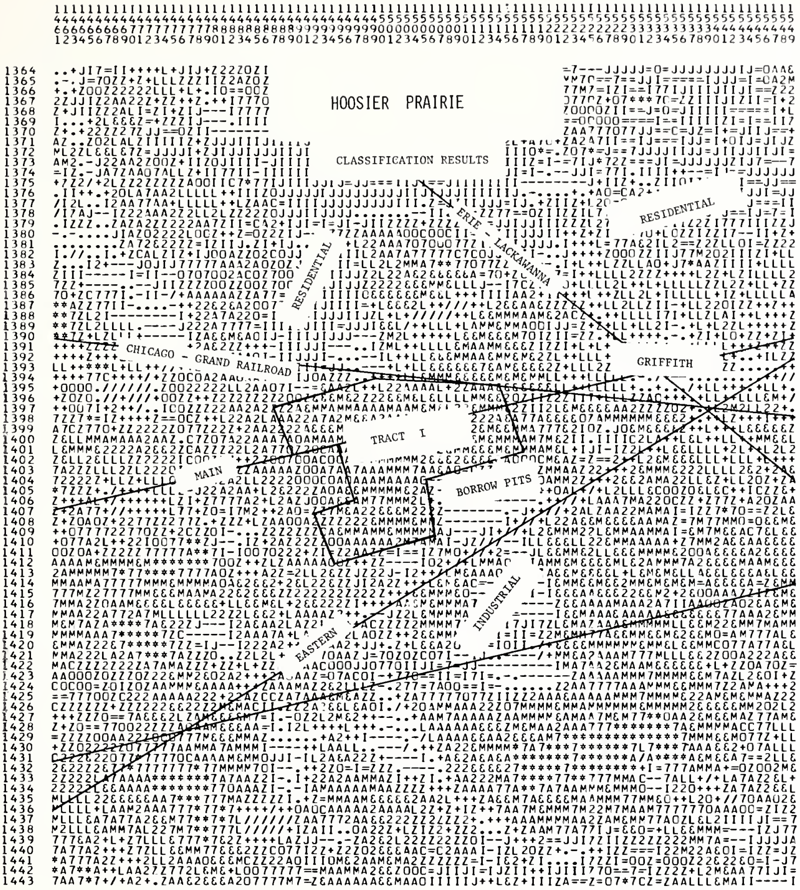

HOOSIER PRAIRIE
CLASSIFICATION RESULTS
ERIE LACKAWANNA
RESIDENTIAL
RESIDENTIAL
CHICAGO - GRAND RAILROAD
GRIFFITH
TRACT I
BORROW PITS
MAIN
EASTERN
INDUSTRIAL

FIGURE 1. *Spectral classification of the terrestrial environment of the Hoosier Prairie and surrounding area.*

TABLE 2. *Distribution of informational classes as determined from Landsat data.*

	Spectral Symbols	Pixels	Percent	Hectares
Grass well drained areas	M	77	25.91	31.46
Grass of poorly drained areas	A	77	25.91	31.46
Marsh-shrubs/herbs	&	66	22.24	27.00
Marsh-cattails/herbs	Z	7	2.36	2.86
Brush	7	9	3.03	3.68
Scattered tree groups	2	41	13.80	16.76
Dense trees	L	11	3.72	4.50
Other	0, +	9	3.03	3.68
TOTAL		297	100.00	121.40

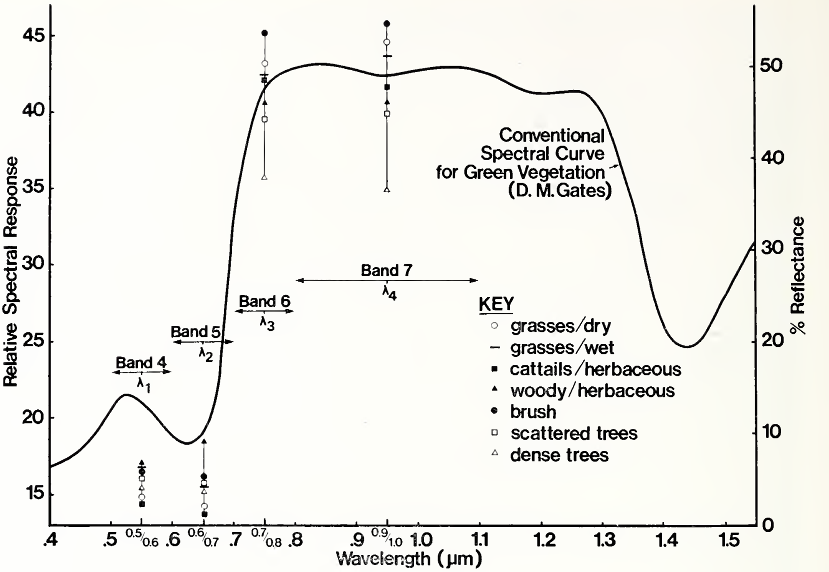


FIGURE 2. *Relative spectral response obtained from seven different vegetative covers.*

Conclusions

Nonsupervised computer-aided classification techniques employed to classify the Hoosier Prairie features with Landsat MSS data showed:

(1) Level I land use categories could be readily identified from Landsat data without the aid of supplemental reference material.

(2) All Level II categories could also be readily identified from Landsat data without the aid of reference material except for the residential classes occurring in vegetated areas. Photointerpretation of aerial photography was required to distinguish this class accurately.

(3) Identification of Level III and IV categories was possible by using ground observations to facilitate interpretation of the classification derived from Landsat data.

Acknowledgment

The authors would like to express their appreciation to Mr. William B. Barnes and Mr. James Keith of the Division of Nature Preserves of the State of Indiana for their assistance in obtaining ground observations.

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Glacial Lake Patoka: A Geomorphic Reinterpretation Using Soil Survey

RUSSELL BOULDING
4725 E. Bethel Lane
Bloomington IN 47401

Abstract

Soil maps were used to examine the relationship between the Illinoian age lacustrine facies of the Atherton Formation in northwestern Dubois County (Glacial Lake Patoka) and the Prospect Formation in the upper Patoka River basin. Most of the areas mapped Prospect Formation are remnants of two distinct topographic surfaces. One, at 550 feet, correlates with a possibly pre-Illinoian stage of Glacial Lake Patoka and the other, at 500 feet, correlates with the Illinoian stage of Glacial Lake Patoka. The 550 foot lake stage has not previously been recognized in the geologic literature. Late Illinoian terraces below the 500 foot lake stage exist along the Patoka River in the vicinity of Jasper in Dubois County. The Sangamon paleosol is formed on all three terrace surfaces, thus the present topography of the lake plain was shaped well before the end of Sangamon time.

Caution is necessary when using soil maps for geological interpretation because soils do not always reflect correctly the underlying parent material. When this limitation is recognized, soil survey can be a valuable aid in reconstructing the Quaternary history of an area.

Introduction

The genesis and morphology of Indiana's soils are closely related to the geological and climatic events surrounding the advance and retreat of continental ice sheets during the Pleistocene. With the exception of residual soils, all soil series in the State can be correlated with one or more of the Pleistocene formations recognized by geologists (2). As a consequence, a detailed soil map can be a valuable tool in reconstructing the Quaternary history of a region. This paper presents the results of using soil survey for this purpose in the upper Patoka River basin in southern Indiana and discusses some of the limitations inherent in relying on published soil maps for geological interpretation. The lacustrine facies of the Atherton Formation and the Prospect Formation were a special focus of this study because the relationship between these two formations is not well understood.

Geomorphic Background

Geologists working in southwestern Indiana around the turn of the century concluded that the flat plain that exists at an average elevation of about 490 feet in the northeastern corner of Pike County and the northwest quarter of Dubois County was created by ponding of the Patoka River at the margin of the Illinoian ice sheet (3,7). The ice sheet also deflected three important tributaries of the East Fork of the White River, which, in combination with a minor tributary of the Wabash River, became integrated into the present Patoka drainage basin. All subsequent discussions of the geomorphology of the Patoka River basin have accepted this interpretation (5,8,10).

The sediments deposited in Glacial Lake Patoka have been mapped as the lacustrine facies of the Atherton Formation on the Geologic

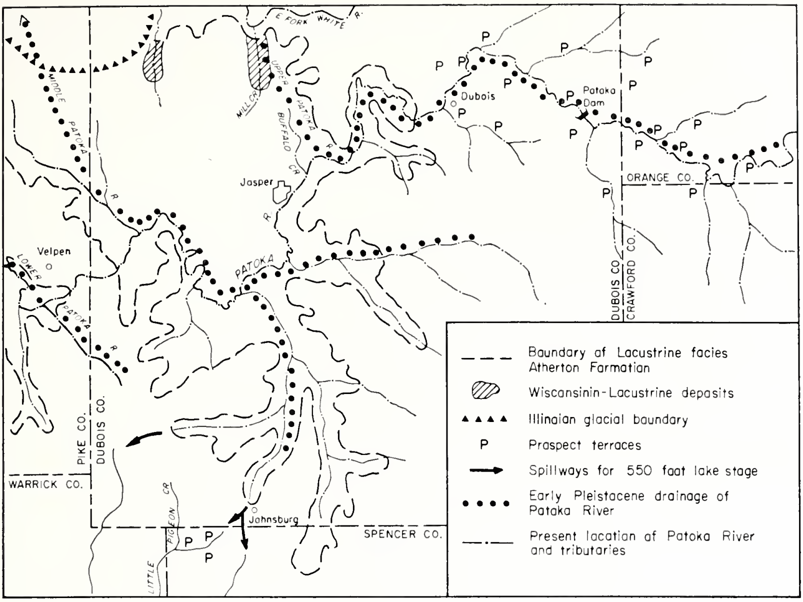
E. FORK WHITE R.
MILL CR.
UPPER PATOKA R.
BUFFALO CR.
MIDDLE PATOKA R.
Dubois
Patoka Dam
Jasper
PATOKA R.
Velpen
LOWER PATOKA R.
ORANGE CO.
DUBOIS CO.
CRAWFORD CO.
PIKE CO.
DUBOIS CO.
WARRICK CO.
SPENCER CO.
Johnsburg
PIGEON CR.
LITTLE
P
Boundary of Lacustrine facies Atherton Formation
Wisconsinin-Lacustrine deposits
Illinoian glacial boundary
Prospect terraces
Spillways for 550 foot lake stage
Early Pleistocene drainage of Patoka River
Present location of Patoka River and tributaries

Figure 1. Pleistocene geology of Glacial Lake Patoka, southwestern Indiana.

Figure 1. *Pleistocene geology of Glacial Lake Patoka, southwestern Indiana.*

Map of the Vincennes Quadrangle (6). This map unit also includes small areas of Wisconsinan lacustrine slackwater clays that lie at a lower terrace level (about 450 feet at Mill Creek) along the East Fork of the White River (1,10). Illinoian glacial till (Jessup Formation) lies at the northwestern margin of Glacial Lake Patoka. Terraces along the upper reaches of the Patoka River, beginning at the town of Dubois in Dubois County and extending well into Orange County, are mapped Prospect Formation (Fig. 1). The Prospect Formation consists of silts, sands and gravels and is found throughout the unglaciated uplands of southern Indiana capping eroded terraces 20 to 50 feet above the present floodplain (12). The relationship of this formation to other unconsolidated deposits is poorly understood because it is rarely well exposed. In the Patoka River basin it predates the deposits of Illinoian Glacial Lake Patoka (5), but the dividing line between the Prospect terraces and the lacustrine Atherton terraces is not clearly defined (Henry Gray, personal communication, October 1976).

Study Methods

Several sources of soils and geologic information were used in this study:

1. Direct field observations during the course of mapping soils in Dubois and Orange Counties.
2. Field sheets completed by other soil scientists working in the

two counties (Robert Wingard and John Bernard, Soil Conservation Service, and Jack Coulter and Gary Hudson, Department of Natural Resources).

3. Published soil and geologic maps of the area (3,4,9,11).

4. Copies of the 7½ minute field sheets for the Geologic Map of the Vincennes Quadrangle (6).

Soil series from the different sources were correlated with the different Pleistocene formations in the study area (Table 1). The relationship of the lacustrine and river terraces in the vicinity of Jasper in Dubois County and upstream into Orange County was examined by transferring areas mapped as terrace soils from soil field sheets to 7½ minute topographic maps. Maximum elevations of individual terraces as determined on the topographic map were plotted on a longitudinal transect of the Patoka River upstream from Jasper (Fig. 2).

Certain limitations should be recognized before making geologic interpretations from soil maps. Soils may not reflect correctly the underlying parent material. This is particularly true of soils with similar taxonomic classification. For example, Otwell (lacustrine), Pekin (river terrace), Tilsit and Zanesville (residual) all appear similar in the field and where terrace material is thin over bedrock or has colluvial material mixed in, it is often difficult to judge whether a soil is formed in terrace material or bedrock residuum. Such errors are not critical in most uses of soil maps because similar soils have similar interpretations for management, but they can be misleading to a geologist trying to interpret the nature of the underlying material.

Soils that would be of great interest to the geologist may not be included in the published soil map of a county because they are of minor extent. A small area of glacial till exists in northwestern Dubois County, but acreages of the applicable soil series are so small that they have been mapped as inclusions with deep loess soils.

Correlations between soil series and tthe Pleistocene formations in Indiana may not always be accurate because similar soil profiles can sometimes develop from differing geologic processes. In Monroe County, for example, Markland, A Wisconsinan lacustrine soil which has carbonates near the surface has been mapped on Illinoian lacustrine materials where the normally leached surface material has been stripped off by erosion (Henry Gray, personal communication, October 1976).

Results

In the vicinity of Jasper there are three distinct terrace levels. The highest terrace exists as eroded remnants ranging in elevation from 500 to 580 feet and is recognized on the basis of soil properties, such as course textures and stratification in the substratum, rather than as a topographic surface. Most occurrences of this terrace are below the 550 foot level, but two remnants at 570 and 580 feet stand within a mile of each other on both sides of Bison Branch of Buffalo Creek, which was the pre-Illinoian outlet of the Upper Patoka River into the White River. This terrace has not previously been recognized

TABLE 1. *Correlations of soil series to Pleistocene Formations in the area of Glacial Lake Patoka.*

Soil Survey	Atherton Formation Illinoian	(lacustrine facies) Wisconsinan	Prospect Formation	Jessup Formation
Dubois County				
Current Survey	Otwell Dubois, Peoga, Pike, Parke, Negley	Montgomery, McGary	Pekin, Bartle, Peoga	[1]
1937 Survey	Haubstadt, Dubois, Robinson, Harbison, Bainbridge	Markland, McGary	Huabstadt, Dubois	Alford, Iva[2]
Pike County				
1938 Survey	Haubstadt, Dubois, Otwell, Robinson, Bainbridge, Calhoun	Markland, McGary, Montgomery	----------------	Alford, Muren, Iva, Eel[3]

[1] Deep loess soils over till are not differentiated from deep loess soils over other material.

[2] Mapped only over Illinoian till.

[3] Deep loess soils over Illinoian till are differentiated from deep loess soils over bedrock by a boundary.

in the geologic literature. The second, intermediate, terrace ranges between 480 and 500 feet and corresponds to the deposits of Glacial Lake Patoka mapped by Fuller and Ashley (3). It is at an elevation of about 500 feet near the White River and slopes gradually to 480 feet at the Patoka River near Jasper. A third terrace lies below the intermediate lake plain and about ten feet above the present flood plain of the Patoka River. Several miles south of Jasper this terrace is about 460 feet in elevation.

All three terraces can be traced along the Patoka River upstream from Jasper (Fig. 2). Only a few remnants of the high terrace exist between Jasper and the Orange County line. Part of the town of Dubois, near Polson Creek, is built on remnants of this terrace which has a maximum elevation of about 550 feet. Another remnant with the same elevation is near the spillway of the Patoka Dam. Terrace elevations range between 540 and 560 feet for about 25 river miles into Orange County about which point the gradient slopes abruptly upward to a gradient of about 10 feet per mile.

The 500 foot terrace is the most extensively developed terrace between Jasper and the Patoka Dam. The maximum elevation of individual terrace remnants is consistently between 500 and 510 feet for a distance of about 30 miles where the lacustrine plain merges with the present floodplain somewhere around the Orange County line. The low terrace seems to follow the gradient of the Patoka River and merges with the 500 foot terrace somewhere in the vicinity of the town of Dubois.

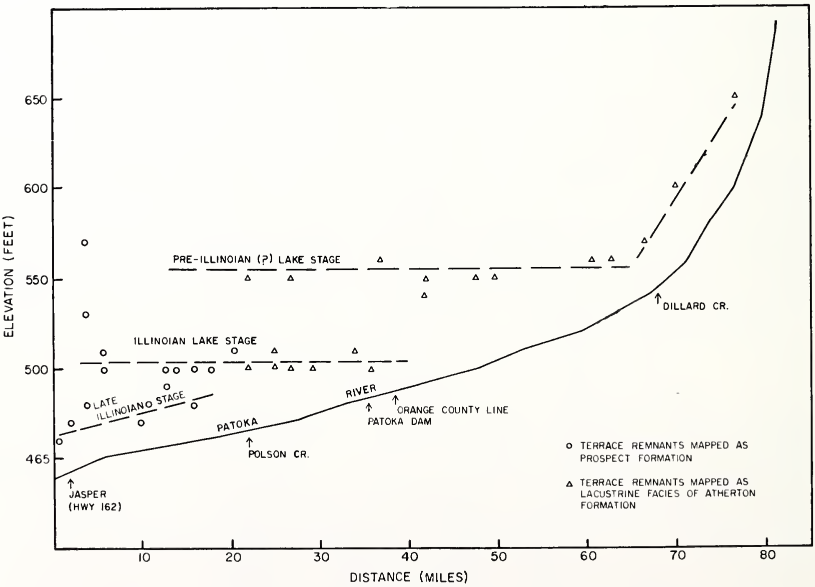

FIGURE 2. *Maximum elevations of terraces along the mainstem Patoka River upstream of Jasper, Dubois County, Indiana.*

The Sangamon paleosol is a ubiquitous feature throughout the lake plain. It is most easily recognized in the well drained lacustrine soils (Pike, Parke and Negley) where a clay loam or sandy clay loam B horizon with hues of 5 or 2.5 YR is covered by a few inches to four or more feet of Peoria loess. The paleosol is developed on all three terrace levels, and seems to follow the present topography of the lake plain very closely. Thus the present topography of the lake plain was shaped well before the end of Sangamon time. The relief of this surface is at least 130 feet in the vicinity of Jasper.

The existence of a lake stage at 550 feet or higher raises the possibility that Glacial Lake Patoka drained through one or more outlets before, or in addition to, the spillway at Velpen that joined the Middle and Lower Patoka Rivers. The hills that surround the lake plains mostly exceed 550 feet in elevation with one notable exception. About a mile southwest of the town of Johnsburg in Dubois County is a drainage divide at an elevation of 510 feet. Several other drainage divides in the same area lie between 540 and 550 feet (Fig. 1).

Interpretation

Most of the areas mapped as Prospect Formation in the Upper Patoka River basin seem to be remnants of two distinct topographic surfaces that are related to two major stages of Glacial Lake Patoka. Thus most of the Prospect terraces along the Patoka River correlate with the lacustrine deposits of the Glacial Lake. More detailed field work needs to be done, but I would like to tentatively propose the following interpretation that I believe fits the presently available data:

1. The high terrace of Glacial Lake Patoka is the result of damming of the early Pleistocene Upper and Middle Patoka River by a pre-Illinoian ice sheet. Maximum elevation of the lake was at least 580 feet, but a relatively stable lake level probably existed at 550 feet. The lake probably had a number of outlets, but the major ones were south into the Ohio River through Little Pigeon Creek and possibly west into the Lower Patoka River near Velpen. The Prospect terraces mapped in the upper reaches of Little Pigeon Creek may be related to this event. The 550 foot Prospect terrace in the Upper Patoka River was either deposited at this time and/or eroded to this level from material deposited during an earlier high base level. If more detailed investigations should prove that the lacustrine soils mapped above 500 feet are not actually water laid, another explanation will have to be found for the 550 foot Prospect terrace.
2. The intermediate terrace of Glacial Lake Patoka is the Illinoian lake stage. The 500 foot Prospect terrace near the Patoka Dam is probably the result of lateral planation of the pre-Illinoian terrace because there is stratigraphic evidence that the material of these terrace remnants is the same age as the 550 foot terrace remnants in the same area (Henry Gray, personal communication, October 1976). Some of the terrace remnants downstream may be depositional rather than erosional.
3. The low terrace is probably related to a late Illinoian stabilization of base level, perhaps due to a readvance of the ice sheet.

Conclusions

The possibility of a pre-Illinoian glacial lake and additional derangement of the Patoka River raises as many questions as it answers. The geomorphic history of the Patoka River is certainly more complex than previously recognized. Careful use of soil maps combined with geological information should increase our understanding of the Patoka's Pleistocene history when more of the River basin is mapped in the course of Indiana's accelerated soil survey program.

Acknowledgments

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Chemical and Mineralogical Characteristics of Selected Indiana Soils[1]

D. W. NELSON, C. B. ROTH and L. E. SOMMERS
Agronomy Department
Purdue University, West Lafayette, Indiana 47907

Abstract

Chemical and mineralogical characteristics of 48 selected Indiana soils representative of many of the major soil series in the state were determined. Data for soils were grouped into 7 textural classes and average values for the classes were obtained for each parameter measured. The amount of organic C, total N, ammonium fixing capacity, total P, total S, and cation exchange capacity in soils tended to decrease as soil texture became coarser. The proportion of quartz, vermiculite, and amorphous material in the clay fraction, the proportion of organic C extractable with pyrophosphate and hot water, and the proportion of total P present as inorganic P in soils increased as soil texture became coarser. The clay fraction of the Indiana soils studied contained higher proportions of micaceous (illite) and chlorite-like minerals than other constituents. A substantial proportion of the total N in soils is fixed NH_4-N with the heavier-textured soils possessing relatively high NH_4 fixing capacities, i.e. 100 ug NH_4-N/g. The organic C:N:S:P ratio is very constant in Indiana soils averaging 11:1:1.5:0.15. There were close relationships between clay content and organic C, total N, total P, and total S in soils. The mica content of soils was closely related to fixed ammonium content, cation exchange capacity, and ammonium fixing capacity.

Agronomists are often asked to make recommendations on nitrogen, phosphorus, and potassium fertilizer application rates for Indiana soils. They are often asked specific questions concerning various fertilizer management practices and, in recent times, they are asked to calculate application rates for animal, municipal and industrial wastes which may be effectively applied to various soils in the state. Arriving at suitable recommendations requires detailed knowledge of the characteristics of the soil involved. Typically, to make an accurate recommendation, it is necessary for the agronomist to travel to the site, take soil samples, and have the samples characterized. In many cases, the time required for sample collection and analysis is lengthy, and thus, a general knowledge of the mineralogical and chemical properties of Indiana soils would allow rapid evaluation of management alternatives.

Some relevant data on Indiana soils are contained in the soil survey reports developed for each county; however, many of the characteristics of the soil which are needed for use in making management recommendations are not available in soil survey bulletins. Therefore, our research group initiated a study of the chemical and mineralogical characteristics of Indiana soils representing many of the major soil series within the state. The objectives of this study were: (1) to obtain detailed information on the chemical and mineralogical composition of many of the major soil series in Indiana, (2) to group the soils studied into seven textural classes and attempt to generalize some of the observed characteristics of each class, and (3) to determine the interrelationships between various soil components. The latter objective is important because in the case of a soil where limited data is available, it may be appropriate to relate what is known about the composition to other parameters for which we have no information. The authors realize that it is difficult to group data for soil properties because of the inherent variability in soils belonging to a given textural class. However, to make the data obtained suitable for publication grouping of soils by textural classes was necessary. Data for individual soils studied may be obtained directly from the authors.

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[1] Journal Paper No. 6537, Purdue University Agricultural Experiment Station.

Materials and Methods

The surface soils (0-20 cm) used in this investigation were collected by Wischmeier and Mannering (10) during studies to evaluate the erodibility of Indiana soils. These studies involved determination of soil physical properties, but relatively little data was obtained on chemical and mineralogical properties. To expand the textural range and soil slope conditions covered in this study, additional soils were collected from throughout Indiana to supplement those used by Wischmeier and Mannering. All samples were obtained from sites which had been cropped for many years and identification relative to soil series was provided by soil survey personnel. All soils were air-dried, ground to pass an 80-mesh sieve, and stored in sealed plastic bags until use.

Twenty two chemical and mineralogical properties were determined for each of the soils included in this study. Clay, silt, and sand were measured by the pipet method outlined by Kilmer and Alexander (4). Kaolinite, inorganic amorphous material, montmorillonite, mica, quartz, chlorite, vermiculite, pyrophosphate extractable C and hot water extractable C were determined by procedures outlined by Roth, Nelson, and Römkens (8). Organic C was determined by the method of Mebius (5). Total N was estimated by the method of Nelson and Sommers (7). Fixed ammonium N was measured by the method of Silva and Bremner (9). Organic N was calculated as the difference between total N and fixed ammonium N. Total P was determined by the method of Sommers and Nelson (10). Organic P was estimated by the method of Mehta *et al.* (6). Inorganic P was calculated as the difference between total P and organic P. Total S was determined by procedures outlined by Bardsley and Lancaster (1). Cation exchange capacity was measured by the method of Edwards (2). Ammonium fixing capacity was determined by the difference in fixed ammonium N before and after treating 1 gram of soil with 1000 μg of ammonium N for a period of 24 hours at 22C.

Results and Discussion

Table 1 presents data on the average particle size distribution in Indiana soils belonging to seven textural classes. Since the basic criteria for grouping soils was particle size distribution, the data obtained are characteristic for the textural classes included in the study.

TABLE 1. *Particle size distribution in Indiana soils as related to textural classification.*

Textural class	No. of soils	Particle size distribution*		
		Clay	Silt	Sand
		%	%	%
Silty clay loam	4	36.5±1.9	49.8±5.6	8.0±5.5
Clay loam	2	24.5±0.7	34.5±7.8	28.5±0.7
Silt loam	24	16.1±3.2	66.4±7.1	13.3±8.8
Loam	9	17.2±2.4	43.2±5.3	36.1±5.9
Sandy loam	6	9.3±2.5	25.5±6.0	61.7±5.0
Loamy sands	3	4.0±1.0	9.3±1.2	85.3±1.2

* Values given are averages and standard deviations for the soils making up each textural class.

The average distribution of inorganic materials present in the clay fraction of Indiana soils belonging to seven textural classes is presented in Table 2. Surprisingly, the clay fraction of Indiana soils is rich in micaceous and chlorite-like minerals relative to kaolinite and montmorillonite. These findings are somewhat different from those of White *et al.* (12) who observed that Indiana surface soils contain substantial proportions of quartz and kaolinite in addition to mica, and different from those of Fehrenbacher *et al.* (3) who reported that loess soils from southwestern Indiana contain considerable montmorillonite. Other clay materials make up substantial proportions of the clay minerals in the soils studied, with the exception of vermiculite (< 10% of the total clay minerals). It is interesting to note that the proportions of inorganic amorphous material, quartz, and vermiculite tended to increase as the clay content of the soils studied decreased. The proportion of mica present in the clay fraction of Indiana soils tended to decrease as the sand content of the soils increased. The proportion of kaolinite, montmorillonite and chlorite-like minerals present in the clay fractions of Indiana soils studied was not related to soil textural class.

Table 3 presents data on the average organic C content and forms of organic C in Indiana soils belonging to seven textural classes. The average organic C concentration for the soils in each textural class and the standard deviation of C contents for soils within classes are presented. It is interesting to note that the coefficient of variation

TABLE 2. *Distribution of inorganic materials in the clay fraction of Indiana soils as related to textural class.*

Textural class	No. of soils	Mica	Koal-inite	Amorp. material	Montmor-illonite	Quartz	Chlorite	Vermic-ulite
		— — — — — —		% of clay fraction		— — — — — —		
Silty clay loam	4	45.8	9.2	6.1	6.7	7.5	19.4	5.3
Clay loam	2	37.1	8.2	6.5	13.9	9.0	22.4	2.9
Silt loam	24	21.1	16.1	14.3	14.9	10.6	19.3	3.7
Loam	9	34.5	9.9	12.3	12.3	11.7	15.8	3.5
Sandy loam	6	28.0	12.9	12.9	8.6	12.9	15.1	9.6
Loamy sand	3	20.0	15.0	15.0	10.0	17.5	15.0	7.5

TABLE 3. *Organic C content and forms of organic C in Indiana soils as related to textural class.*

Textural class	No. of soils	Organic C*	Org C forms: Pyrosphosphate ext.	Org C forms: Hot water ext.
		%	— — % of org C — —	
Silty clay loam	4	2.260±1.012	22.6	3.7
Clay loam	2	1.375±0.488	20.0	3.3
Silt loam	24	1.103±0.269	27.6	4.1
Loam	9	1.492±0.570	26.9	4.1
Sandy loam	6	1.197±0.637	39.4	7.0
Loamy sand	3	0.573±0.240	34.0	4.5

* Values given are averages and standard deviations for the soils making up each textural class.

for data on organic C content varied from 30 to 50%. This finding suggests that organic C contents of soils within a given textural class is not extremely variable because differences in organic C contents were greater between soils of varying textural classes than for soils within a given textural class. The amount of organic carbon present in the Indiana soils studied tended to decrease as the texture of the soils becomes coarser. However, some poorly-drained, coarse textured soils contained substantial organic C.

The proportion of organic C extractable with sodium pyrophosphate varied from 20 to 39% for the soils studied. The proportion of organic C in soils extractable with pyrophosphate tended to increase as soils become coarser in texture. This finding suggests that even though coarser-textured soils tend to have low amounts of C, the organic C present in these soils may be effective in promoting aggregation and may be readily available for decomposition by microorganisms. The latter point is important because decomposition of soil organic matter releases significant amounts of N, P, and S for plant growth. The fraction of soil organic matter extractable with pyrophosphate appears to be more active in binding inorganic materials into aggregates than other soil organic matter fractions. The proportion of organic C extractable with hot water varied from 3.3 to 7% within the textural classes studied. There was a tendency for the proportion of organic C extracted by hot water to increase as soil texture became coarser.

Hot water extracts polysaccharides, an organic C fraction which has been implicated in promoting aggregation and improving soil structure. These findings would suggest that coarser-textured Indiana soils may have the potential to be well aggregated due to pyrophosphate-extractable and water-soluble organic materials even though the absolute amount of organic carbon in these soils is relatively low.

The average total N contents, NH_4^+ fixing capacities, and forms of N in soils studied belonging to seven textural classes is given in Table 4. Within a given textural class, the coefficient of variation for total N content varied from 20 to 40%. The total N contents of Indiana soils tended to decrease as soils became coarser in texture.

TABLE 4. *Total N content, ammonium fixing capacity, and forms of N in Indiana soils as related to textural class.*

Textural class	No. of soils	Total N	NH_4^+-fixing capacity*+	N forms in soil Fixed NH_4^+-N	 Org N
		ppm	ug NH_4^+-N/g soil	— % of total N —	
Silty clay loam	4	2297±883	160(439)	13.6(854)	86.4
Clay loam	2	1420±424	108(441)	17.7(1024)	82.3
Silt loam	24	1205±254	24(149)	10.5(783)	89.5
Loam	9	1360±436	25(145)	11.2(884)	88.8
Sandy loam	6	1168±490	16(172)	6.2(774)	93.8
Loamy sand	3	563±154	2(50)	4.6(650)	95.4

* Values in parenthesis are ug NH_4^+-N fixed per gram of clay.

+ Values in parenthesis are ug fixed ammonium N per gram of clay.

Likewise, the NH_4^+ fixing capacity of silty clay loam soils was much higher than that of silt loams or sandy soils. In fact, the NH_4^+ fixing capacity of silt loams, loams, sandy loams and loamy sands was extremely low (i.e., less than 25 µg NH_4^+-N fixed/g soil). It is interesting that the NH_4^+ fixing capacity, when expressed as µg of NH_4^+-N fixed per g of clay, is much higher in silty clay loams and clay loam soils than in coarser-textured soils. The ammonium fixing capacity of the clay fraction of loamy sand soils is only 50 µg of NH_4^+ -N/g clay.

Data on forms of N in soils studied indicate that fixed NH_4^+-N constitutes a substantial proportion of the total N present in loam, silt loam, clay loam and silty clay loam soils. In the two clay loam soils, 17.7% of the total N was present as fixed NH_4^+-N. Compared to values for other midwestern soils, a very high proportion of the total N in Indiana soils is present as fixed NH_4^+-N. Even in coarse-textured soils, from 5 to 6% of the total N was present as fixed NH_4^+-N. These findings are significant because unlike other forms of N in soils, microbial activity does not release fixed NH_4^+ for plant uptake. Expressing the fixed ammonium content of soils on the basis of clay demonstrated that clay loam soils have an average of 1024 µg NH_4^+-N/g clay. Similar expressions for other soil textural classes illustrated that the fixed ammonium content of soil clays varied from 650 to 884 µg NH_4^+-N/g clay. The proportion of total N in soils which was organic tended to increase as soil textures became coarser. This finding was expected since the proportion of total N present as fixed ammonium in heavy-textured soils was much higher than that of coarse-textured soils.

Table 5 presents data on the average P content and forms of P. As expected, the total P concentration tended to be higher in heavier-

TABLE 5. *Total P content and forms of phosphorus in Indiana soils as related to textural class.*

Textural class	No. of soils	Total* P	Phosphorus Forms	
			Organic P	Inorganic P
		ppm	— % of total P —	
Silty clay loam	4	705± 40	44.1	55.9
Clay loam	2	588±230	22.1	77.9
Silt loam	24	424±137	36.3	63.7
Loam	9	433±211	31.9	68.1
Sandy loam	6	301± 76	30.9	69.1
Loamy sand	3	340± 50	19.4	80.6

* Values given are averages and standard deviations for the soils making up each textural class.

textured soils and there was a tendency for total P content to decrease as soil texture became coarser. This finding is to be expected because soil P is normally associated with organic matter and clay and data presented previously have indicated that both clay content and organic matter content are lower in coarser-textured Indiana soils as compared to silty clay loam, clay loam, and silt loam soils. The proportion of total P present as organic P tended to be higher in heavier-textured soils as compared to coarser-textured soils. Conversely, the proportion of total P present as inorganic P tended to be higher in lighter-textured soils as compared to heavier-textured soils. This finding is important because it suggests that those soils which are low in total P contain P forms which are most readily available for plant growth (i.e., inorganic P forms), whereas those soils which are high in total P contain a lower proportion as inorganic P. Therefore, it can be concluded that most of the soils studied contain appreciable amounts of phosphorus in inorganic forms which will serve as a source of plant-available P for the years to come.

Table 6 gives data on the average total S content, cation exchange capacity (CEC) and organic C:N:S:P ratios of Indiana soils. All of the Indiana soils studied had appreciable concentrations of total S (i.e.,

TABLE 6. *Total S content, cation exchange capacity, and organic C:N:S:P ratios of Indiana soils as related to textural class.*

Textural class	No. of soils	Total S	Cation exc. cap.*	Org C:Org N:Org S:Org P
		ppm	me/100 g	
Silty clay loam	4	1905±106	35.0± 0.1(95.9)	12.1:1:1.5:0.24
Clay loam	2	1755± 7	29.9±10.0(122.0)	11.6:1:1.5:0.11
Silt loam	24	1386±140	12.1± 2.9(75.2)	10.2:1:1.3:0.14
Loam	9	1390±136	13.9± 6.3(80.8)	12.4:1:1.3:0.13
Sandy loam	6	1125±139	7.9± 3.4(84.9)	8.9:1:1.2:0.10
Loamy sand	3	1032±159	4.2± 0.9(105.0)	12.1:1:2.3:0.15

* Values in parenthesis are me of cation exchange capacity per 100 g of clay. It should be noted that a substantial portion of total exchange capacity resides in soil organic matter.

greater than 1000 ppm). It was also interesting to note that the coefficient of variation for total S within soil textural classes was from 1 to 15%. This would suggest that the S content of the soils studied was relatively uniform within a given textural class. The total S content of soils was highest in heavier-textured soils and decreased as soil texture becomes coarser. This finding is expected because most of the total S in soils is associated with soil organic matter, and it has been shown previously that the organic matter content of the soils studied was considerably higher in heavier-textured soils than in lighter-textured soils.

The average CEC of Indiana soils varied from 4.2 to 35 me per 100 grams over the textural classes studied. The CEC values decreased markedly as the sand content of the soils increased. Heavier-textured soils contained markedly higher CEC values than did coarser-textured soils. When CEC was expressed as me per 100 grams of clay, there was little difference in the values over the soil textural classes studied. However, soils belonging to the clay loam class had higher CEC per gram of clay than did soils belonging to any other textural class. It is important to recognize that a substantial portion of the CEC of the clay fraction is due to organic matter associated wih the inorganic constituents.

Organic C:N:S:P ratios were calculated to evaluate the consistency of soil organic matter composition over the textural classes. It is interesting to note that the average C:N:S:P ratio in soil organic matter was extremely consistent (average 11:1:1.5:0.15) within the textural classes studied. Only silty clay loam soils contained an abundance of organic P relative to C, N, and S in organic matter, whereas loamy sand soils were enriched in organic S. The fact that these ratios are constant over the wide range of soil types studied, suggest that a measurement of one parameter, such as organic C or organic N, would allow an investigator to estimate the composition of organic matter in any Indiana soil developed under similar conditions. The consistency of this ratio also indicates that cropping has resulted in proportional decreases in C, N, S, and P in the soil during the time net decomposition of soil organic matter has occurred.

All data on soil chemical and mineralogical analyses were subjected to linear correlation analysis. Table 7 presents a summary of correlations involving clay, mica, and organic carbon contents with other chemical properties of Indiana soils. Due to the relatively large number of soils studied, correlation coefficients (r) of greater than 0.35 are sufficient for significance ($p=0.05$). In addition to the positive correlations summarized in Table 7, a large number of other statistically significant correlations were obtained; however, they were not considered useful relationships for understanding soil differences.

The expected interaction between clay and soil organic matter is readily apparent from the correlations between clay, organic C, total N, total P and total S. These relationships are due to: (1) the stabilizing influence of clay on the rate of residue decomposition and thus the resultant organic matter content; (2) the main constituents of soil

TABLE 7. *Summary of correlations involving clay content, mica content, and organic C content with other chemical properties of Indiana soils.*

Correlation parameters	No. of soils	Correlation Coefficient (r)
Clay with Organic C	48	+0.54
Clay with Total N	48	+0.64
Clay with Total P	42	+0.53
Clay with Total S	42	+0.85
Clay with Fixed NH_4^+-N	48	+0.78
Clay with CEC	42	+0.79
Clay with NH_4^+ Fixing Cap.	44	+0.78
Mica with Fixed NH_4^+-N	42	+0.94
Mica with CEC	42	+0.82
Mica with NH_4^+ Fixing Cap.	39	+0.84
Mica with Organic C	42	+0.41
Mica with Total N	42	+0.47
Organic C with Total N	48	+0.94
Organic C with Organic N	48	+0.95
Organic C with Total P	42	+0.50
Organic C with Organic P	42	+0.57
Organic C with Total S	42	+0.27
Organic C with Pyrophosphate Sol. C	42	+0.76
Organic C with Hot H_2O Sol. C	42	+0.76

organic matter are C, N, P and S; (3) C, N, P and S in soil organic matter are present in nearly consistent ratio proportions. Numerous other studies have demonstrated the close relationships between these soil components. A result of the clay-organic matter association is the correlation with CEC. Negative charges originating from isomorphous substitution in clays and C, N, P and S functional groups in organic matter are responsible for the CEC of soils.

Clay content was also related to fixed NH_4^+-N content and NH_4^+ fixing capacities of the soils studied. This finding was expected because clay minerals such as illite and vermiculite are responsible for fixing NH_4^+ in soils and previous work (D. W. Nelson, Purdue University, unpublished data) has established that greater than 95% of the fixed NH_4^+-N in soils is present in the clay fraction.

Correlation data suggests that the micaceous mineral fraction is responsible for the fixed NH_4^+ content and the NH_4^+ fixing capacities of soils studied. These findings are to be expected because the only soils minerals having the capacity to fix NH_4^+ are mica and vermiculite. The vermiculite content of the soils studied was quite low. The cation exchange capacity was also directly related to the micaceous mineral content of the soils studied suggesting that a substantial proportion of the exchange capacity of these soils reside with the mica component. The organic C and total N contents of Indiana soils were not strongly related to soil mica content suggesting that soil organic matter is not predominately associated with the mica component of soil clays.

The organic C content was directly related to the amounts of total N and organic N present in Indiana soils. This finding has been reported in many studies of other soils in the United States. The total P and organic P contents of the samples studied were not strongly related to the organic C concentration in Indiana soils. It is surprising that there was not a good correlation between organic C and organic P content of the soils because both are components of soil organic matter. The finding that the organic P content of soils is variable in relation to the organic C content suggests that organic P is not accumulated in fixed proportion to the amount of organic C incorporated during soil organic matter synthesis. There was no relationship between the amount of organic C and total S present in Indiana soils. This finding is very difficult to understand because in excess of 95% of the total S in soils is present in organic form. The amount of pyrophosphate soluble-C and hot water soluble-C were directly related to the amount of organic C present in the soil, suggesting that a given proportion of the organic C is extractable with sodium pyrophosphate and with hot water. This finding suggests that similar types of organic matter components are present in most Indiana soils.

Conclusions

The following conclusions may be drawn from this study: (1) Indiana soils have a reasonably uniform clay mineralogy and the < 2 micron fraction of Indiana soils contain higher proportions of micaceous and chlorite-like clays as compared to other minerals, (2) the organic matter contents of Indiana soils are directly related to soil texture; heavier-textured soils have proportionately more soil organic matter than do coarser-textured soils. The organic matter present in Indiana soils is apparently uniform in composition because the ratios of organic C:N:S:P are very consistent over all textural classes, (3) Indiana soils generally have low NH_4^+ fixing capacities except for silty clay loams and clay loam soils where NH_4^+ fixing capacities greater than 100 μg NH_4^+-N/g soil are common, (4) Indiana soils have a larger proportion of total N present as fixed NH_4^+-N than other soils of the humid cornbelt, (5) the total C content of Indiana soils is reasonably high suggesting minimal probability for need of S fertilization, (6) the cation exchange capacity of heavier-textured soils exceeds 30 me/100 g and decreases proportionately as the clay and organic C contents decrease, (7) the micaceous mineral content is closely related to the fixed NH_4^+ content, the CEC, and the NH_4^+ fixing capacity, (8) the amounts of organic C, total N, total P, and total S are positively correlated with the clay content of Indiana soils.

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An Analysis of Worst Case Meteorological Days Versus Poor Dispersion Days During Emergency Episodes

David R. Maxwell, Indiana State Board of Health
Air Pollution Control Division, Indianapolis, Indiana 46206

Abstract

An analysis is made to distinguish "worst case" meteorological days from poor dispersion days. The characteristics of each condition are evaluated and their contribution to poor air quality and Emergency Episodes described. Pollutant notification levels for the State of Indiana and Air Stagnation Advisory Criteria used by the National Weather Service are listed.

There are two distinctly different meteorological conditions which may produce such poor air quality in a particular area that the National Ambient Air Quality Standards (NAAQS) may be exceeded. These conditions are classified as "worst case" meteorological days or poor dispersion days. A "worst case" meteorological day can be defined as a given day in which the meteorological conditions are such that high air pollutant concentrations occur over regions downwind from a point source or several sources of pollution. The poor air quality is usually confined to a small region in the path of looping or fumigation (inversion breakup) plumes, with the latter resulting in extremely high concentrations lasting from only a few minutes to less than an hour, unless an onshore sea breeze condition exists which could prolong the problem for several hours. Areas outside of the plume path may experience excellent dispersion while the NAAQS may be exceeded for the small territory within the plume path.

Poor dispersion days occur when the atmosphere is very stable and large temperature inversions prevail. These conditions are associated with a quasi-stationary high pressure system manifested by a very stable temperature profile, light winds, weak vertical motion, and no precipitation. When these meteorological conditions are expected to continue for at least 36 hours, the nearest National Weather Service Forecast Office may issue an Air Stagnation Advisory (ASA) for the affected region. The ASA is a special bulletin used to warn the general public that stagnant atmospheric conditions are expected which could cause increased concentrations of air pollutants near the ground. An ASA checklist (Table 3) is used by Weather Service forecasters to help determine whether an ASA should be issued for a specific region. Poor dispersion days imply that the regional air quality is poor, although no NAAQS may be exceeded. Pollutant notification levels for Indiana are included in Table 2.

"Worst case" days are characterized by nearly constant wind direction with wind speeds usually ranging from 8 to 12 knots, atmospheric stability classifications changing from unstable during daylight hours to slightly unstable at night, mixing heights in excess of 1500 meters, generally fair skies with scattered high clouds, very good visibility, and a heavily concentrated looping plume during the strongest

TABLE 1. *Characteristics of "Worst Case" Meteorological Day Versus Poor Dispersion Day.*

Meteorological Parameter	"Worst Case" Day	Poor Dispersion Day
Wind direction	Nearly constant all day	Variable
Wind speed	8-12 knots	Light; sometimes calm, always less than 5 knots
Average mixing height	Greater than 1,500 meters	Below 500 meters
Temperature profile	Superadiabatic lapse rate	Strong inversion
Characteristic plume	Looping	Fanning
Atmospheric stability	Unstable	Very stable
Cloud cover	Usually scattered high clouds	Usually clear
Visibility	Very good, 10-20 miles	1-4 miles; obscurations due to smoke, fog and/or haze)

periods of vertical mixing. Poor dispersion days usually occur during the summer and autumn months in the midwest when temperature inversions and stagnant air associated with slow moving synoptic scale high pressure systems engulf the central portion of the United States and dominate the weather pattern for a week at a time. "Worst case" days are most frequent during the spring and early summer when the atmosphere is relatively unstable and daylight hours longer. Table 1 lists the meteorological parameters and characteristic features of both poor dispersion and "worst case" days.

The frequencies at which "worst case" and poor dispersion days occur vary from year to year at each of the National Weather Service stations in the midwest. Poor dispersion days are largely dependent on a synoptic scale mass of stagnant air that covers a large portion of the country and the transport of ozone and other pollutants that are carried along with this system.

TABLE 2. *Pollutant Notification Levels for Indiana.*

Pollutant	Alert	Warning
Particulate APC 12R	3.0 COH (24-hour average)	6.0 COH (24-hour average)
Particulate Proposed APC 12	Same	5.0 COH (24-hour average)
SO_2 APC 12R	0.30 ppm (24-hour average)	0.60 ppm (24-hour average)
SO_2 Proposed APC 12	0.30 ppm (4-hour average)	0.35 ppm (4-hour average)
NO_2 APC 12R	1. 0.60 ppm (1-hour average) or 2. 0.15 ppm (24-hour average)	1. 1.20 ppm (1-hour average) or 2. 0.30 ppm (24-hour average)
NO_x Proposed APC 12	Same	Same
O_x APC 12R	0.10 ppm (1-hour average)	0.40 ppm (1-hour average)
O_3 Proposed APC 12	Same	Same
CO APC 12R	15 ppm (8-hour average)	30 ppm (8-hour average)
CO Proposed APC 12	Same	Same

For all Proposed APC 12 warning pollutant levels the meteorological conditions must be such that pollutant concentrations can be expected to remain at the above level for twelve (12) or more hours or increase. An Air Pollution Emergency will be called for both APC 12R and for Proposed APC 12 when a warning level for the respective regulations, has been exceeded and (1) the concentrations of the pollutant(s) are continuing to increase or, (2) the Technical Secretary of the Air Pollution Control Board determines that conditions will continue to increase because of meteorological or other factors.

TABLE 3. *ASA Check Sheet (From the National Weather Service)*

Morning Winds	> 10 K	STOP
	≤ 10K	-1
	≤ 8K	$+1$
	≤ 6K	$+2$
Afternoon and Early Tonight Winds	> 11 K	STOP
	≤ 11K	-1
	≤ 8K	$+1$
	≤ 6K	$+2$
Morning Mixing Heights	> 1500m	STOP
	≤ 1500m > 750m	-1
	≤ 750m > 500	0
	≤ 500m	$+1$
Afternoon Ventilation Factor	$> 8000\,\text{m}^2/\text{s}$	STOP
	$\leq 8000\,\text{m}^2/\text{s} > 6000\,\text{m}^2/\text{s}$	-2
	$\leq 6000\,\text{m}^2/\text{s} > 4000\,\text{m}^2/\text{s}$	0
	$\leq 4000\,\text{m}^2/\text{s}$	$+1$

Both "worst case" and poor dispersion days have distinguishing characteristics, however, both may result in violations of national air quality standards and make breathing more difficult and hazardous for the people in affected areas. "Worst case" days, although more severe for the limited territory that is affected, are less disturbing to the environment than the wide-ranging poor dispersion days that are associated with periods of air stagnation which may last for a week or more.

DECISION (Based on algebraic sum of weighted parameters)
Yes (ASA called) $+3$, $+2$
Marginal Yes $+1$
Marginal No 0
No for negative values and "stop"

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Effect of Nitrogen Fertilization on Tiller Population of Cool-Season Grasses

C. L. Rhykerd, B. O. Blair, C. H. Noller, R. E. Mullen, J. M. Hertel,
and J. J. Vorst, Departments of Agronomy and Animal Sciences
Purdue University, West Lafayette, Indiana 47907

Abstract

On April 8, 1966 an experiment was iniated on the Purdue University Agronomy Farm at Lafayette to determine the response of cool-season grasses to nitrogen fertilization. The soil type on the experimental area was Chalmers silty clay loam.

The four cool-season grasses included in the experiment were Potomac orchardgrass (*Dactylis glomerata* L.), Kentucky 31 tall fescue (*Festuca arundinacea* Schreb.), Lincoln smooth bromegrass (*Bromus inermis* Leyss.), and reed canarygrass (*Phalaris arundinacea* L.). Nitrogen, as ammonium nitrate, was broadcast at rates of 0, 14, 28, 56, 112, 224 and 448 kg/ha per harvest beginning in the spring of 1967. Three replications were included in the experiment. The initial application of nitrogen was in early April and the following applications immediately after each hay harvest. Nitrogen was not applied after the last cutting of each year.

Morphological characteristics were used as a guide to cutting frequency. Orchardgrass and tall fescue head in early May and the regrowth does not joint thus permitting five cuttings annually on a cutting schedule of every five weeks. Reed canarygrass and smooth bromegrass head in mid-May and the regrowth joints. Six to seven weeks are required for stem elongation. Therefore, only four cuttings of these two grasses were obtained annually.

Yield data indicate that approximately 250 kg/ha of nitrogen are required annually to obtain high yields (16 tons per ha or more under good growing conditions) of these grasses and that possibly even higher rates are needed for maximum yield and quality. After this experiment had been underway for six years, tiller counts were taken following the first cutting in 1973 to determine the effect of nitrogen fertilization on tiller population. Excellent stands of tall fescue, orchardgrass, and reed canarygrass were still present at all levels of nitrogen after six years of nitrogen treatments. However, smooth bromegrass was completely eliminated in all three replications of the two highest nitrogen rates. The stands of smooth bromegrass were satisfactory at the lower four rates of nitrogen after six years.

The results of this study indicate that tall fescue, orchardgrass, and reed canarygrass meadows can tolerate nitrogen applications in excess of 1,792 kg/ha annually when applied in four or five split applications. Smooth bromegrass appears sensitive to rates of nitrogen in excess of 448 kg/ha annually applied in four split applications.

Introduction

About 10 years ago Purdue University scientists demonstrated that alfalfa-grass mixtures were capable of yielding more than 16 tons/ha of hay containing nearly 3,000 kg of protein (4). However, at about that same time alfalfa weevil appeared in southern Indiana and it soon became apparent that unless effective insecticides and/or resistant germplasm were found it would not be possible to continue to produce alfalfa in Indiana. Therefore, agronomists began looking for alternative forage crops. Because of the availability of low cost commercial nitrogen interest developed relative to the yield potential of cool-season grasses when liberally fertilized with nitrogen. Consequently, the following experiment was initiated at the Purdue University Agronomy Farm to study the effect of nitrogen on yield and persistence of stands of four cool-season perennial grasses.

Materials and Methods

On April 8, 1966 an experiment was initiated on the Purdue University Agronomy Farm at Lafayette to determine the response of cool-season grasses to nitrogen fertilization. Potomac orchardgrass (*Dactylis glomerata* L.), Kentucky 31 tall fescue (*Festuca arundinacea* Schreb.), Lincoln smooth bromegrass (*Bromus inermis* Leyss.), and reed canarygrass (*Phalaris arundinacea* L.) were seeded individually with oats (*Avena sativa* L.) as a companion crop. The soil type was Chalmers silty clay loam. At time of seeding 342 kg/ha of 25-25-0 were applied. On July 22 the oat crop was harvested and the straw removed.

Plots in triplicate were established in April, 1967 on the four grasses. Nitrogen, as ammonium nitrate, was broadcast at rates of 0, 14, 28, 56, 112, 224, and 448 kg/ha of actual nitrogen per harvest. The initial application of nitrogen was made in early April and the following applications immediately after each harvest. Nitrogen was not applied after the last cutting of each year.

The growth habit of each grass determined the cutting frequency. Five cuttings were obtained annually from orchardgrass and tall fescue since these grasses head in early May and the regrowth does not joint. Consequently, orchardgrass and tall fescue could be harvested at approximately five-week intervals. Smooth bromegrass and reed canarygrass head about the middle to the latter part of May and the stems of the regrowth joint. Six to seven weeks are required for stem elongation to ensure rapid regrowth and persistence of stands of these two grasses. Thus, only four cuttings of smooth bromegrass and reed canarygrass were obtained annually.

Lime was applied prior to seeding to raise the soil pH to 6.8. Phosphorus and potassium were added annually. In 1967, phosphorus and potassium were applied at rates of 112 and 336 kg/ha, respectively. In 1968, and each succeeding year, potassium was applied at a rate of 336 kg/ha in spring and again in late summer while phosphorus was applied each spring at the rate of 112 kg/ha.

The experiment was terminated immediately following the first cutting in 1973. Stand counts were taken at that time employing a 0.1 m^2 quadrat.

Results and Discussion

The effect of nitrogen fertilization on forage yields and crude protein concentrations has been published (1, 5, 6). It was demonstrated that these grasses are capable of hay yields of 16 tons/ha or more when properly managed which is comparable to that of high producing alfalfa-grass mixtures. When stands are pure grass, it appears that approximately 250 kg/ha of nitrogen must be applied annually to produce hay yields of 14 tons/ha under favorable growing conditions and that possibly even higher applications are required for maximum hay and crude protein yield. Crude protein concentration ranged from approximately 10 percent to as high as 30 percent depending on the level of nitrogen applied.

The effect of nitrogen fertilization on tiller population is shown in Tables 1 and 2. The stand of smooth bromegrass was completely eliminated at the two highest rates of nitrogen. However, it is apparent that nitrogen rates producing the highest yields in this study did not have a detrimental effect on tiller density when applied in 4 to 5 split applications. These data are similar to those reported in the literature although previous studies did not include nitrogen fertilizer rates this high (2, 3).

TABLE 1. *Effect of nitrogen fertilization on tiller population of smooth bromegrass and reed canarygrass after a period of six years (1967-1973).*

Species	Nitrogen-kg/ha						
	0	56	112	224	448	896	1796
				Tillers/m^2			
Smooth bromegrass	506	377	441	527	327	0	0
Reed canarygrass	603	463	635	463	667	635*	388

*Avg. of 2 rather than 3 replications.

TABLE 2. *Effect of nitrogen fertilization on tiller population of orchardgrass and tall fescue after a period of six years (1967-1973).*

Species	Nitrogen-kg/ha						
	0	70	140	280	560	1120	2240
				Tillers/m^2			
Orchardgrass	366	474	366	463	517	366	280
Tall fescue	1023	1087	1184	818*	861	990	829

* Only 1 replication.

Tall fescue and reed canarygrass were found to be most tolerant to very high rates of nitrogen. This was especially true of tall fescue as can be seen from Table 2 since the number of the tillers per square meter declined very little at the highest nitrogen level of 2240 kg/ha.

Summary

The results of this study indicate that tall fescue, orchardgrass, and reed canarygrass meadows can tolerate nitrogen rates in excess of 1,792 kg/ha annually when applied in four or five split applications. Smooth bromegrass appears sensitive to annual rates in excess of 448 kg/ha annually when applied in four split applications.

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ZOOLOGY

Chairman: THOMAS JOSEPH, Department of Biology
Indiana University-South Bend, South Bend, Indiana 46615

Chairman-Elect: JOHN O. WHITAKER, JR., Department of Life Sciences
Indiana State University, Terre Haute, Indiana 47807

ABSTRACTS

Numerical Taxonomic Studies of 336 Human Diseases, Using 82 Symptoms. JAMES FERNANDEZ, JOSEPH MATHER, and THEODORE CROVELLO, Biology Department, University of Notre Dame, Notre Dame, Indiana 46556.——Numerical Taxonomy has been described as the numerical evaluation of the affinity or similarity between taxonomic units and the ordering of these units into taxa on the basis of their affinities. We employed procedures of numerical taxonomy to study the relationships among human disease based on 82 symptoms. In addition, we analyzed the relationships among the symptoms as well, to try to delimit meaningful clusters of symptoms. Our data base, a matrix of 336 diseases and the presence or absence of 82 sysmptoms, was obtained from LOGODX, a computer-assisted disease diagnosis system, available commercially from Pelam Inc., Chicago, Illinois 60625. A simple matching coefficient was calculated for all possible pairs between the 336 diseases. These results formed the basis for a cluster analysis using the Unweighted Pair-Group Method. The resulting tree, with its disease groupings, was then compared with conventional ideas of disease classification. As a separate study, we also took a small group of childhood diseases and compared the clustering results of using 82 versus 15 symptoms. To determine the effects of negative matching, we used Jaccard's coefficient of association, and compared the results with those previously obtained with the simple matching coefficient. Our studies have produced some interesting conclusions about the grouping of disease and the inter-relationships between symptoms.

Locomotor Activity Response of *Peromyscus leucopus* to Accelerated Days. BRYAN FLUECKIGER and DON R. TAVES, Indiana University-Purdue University at Fort Wayne, Fort Wayne, Indiana 46805.——Locomotor activity patterns of six male *Peromyscus leucopus* exposed to artificial 21-hour light:dark days indicated that the animals were unable to entrain to this light strategy. Five of six animals underwent periodic phase shifts which resulted in their confining activity to the dark portion of each period. Four control animals successfully entrained to 24-hour light periods.

The Effects of Chlorine on the Development of *Rana pipiens* Eggs: Preliminary Results. BETTY I. TARNOWSKI, Butler University, Indianapolis, Indiana 46208.——Using a continuous flow system, *Rana pipiens* eggs were exposed to chlorine concentrations of 0.04 ppm, 0.3 ppm, 0.6 ppm and 0.9 ppm every 12 hours, for 1 hour duration, for a total of 9 days

(218 hours). Chlorine concentrations were measured by amperometric titration. Prior to hatching, stage 19 (Shumway, 1940), no differences were noticed between the test and the control organisms. Effects of chlorine exposures were observed to have occurred during stages 19-25: embryos exposed to 0.9 ppm and 0.6 ppm chlorine showed a 100% kill following hatching while exposure to chlorine concentrations of 0.3 ppm and 0.04 ppm resulted in a slower developmental rate in addition to reduced survival.

Cytology of an Agametic Gonad Condition in *Drosophila melanogaster*. STEPHEN W. STONER and LEE ENGSTROM, Biology Department, Ball State University, Muncie, Indiana 47306.——One of the earliest visible differentiative events to occur during the development of *Drosophila* is the precocious separation of pale cells from the posterior end of the egg. Some of these pole cells later become the germinal cells of the adult reproductive organs. A strain originally collected in Marguarita Island, Venezuela which possessed temperature-sensitive genetic influences resulting in 20% of the individuals having unilateral or bilateral agametic gonads. Cytological evidence will be presented indicating that adult ovaries and testes possess normal mesodermal components and are attached normally to the germinal disc components; however, no germinal elements are present. We conclude: (1) the genetic influences resulting in agametic gonads prevent normal pole cell differentiation and (2) the formation of all other components of the reproductive systems are under genetic controls distinct from those controlling the germinal elements.

Influence of Gonadal Hormones on RNA Populations Found in the Adrenal Gland of White Mice. WILLIAM P. SHOFNER and TIMOTHY A. STABLER, Department of Biology, Indiana University Northwest, Gary, Indiana 46408.——Stabler and Ungar (Endocrinology, 86:1049, 1970) demonstrated that estradiol, when administered to male white mice, would induce activity of the adrenal enzyme, 20 α-hydroxysteroid dehydrogenase, Testosterone, when administered to nulliparous female white mice, would block such activity. Histochemical studies located the enzyme to be found in the X-zone of the adrenal. Stabler and Wotiz (Am. Zool., 12:675, 1972) demonstrated that the mouse adrenal gland has a specific estrogen receptor. However, this receptor does not follow the accepted model of steroid hormone action as it does not enter the nucleus to interact with the genome.

In an attempt to determine if the receptor-hormone complex is working in the cell cytoplasm at the level of RNA, groups of hormone treated and control animals were set up for both sexes. The adrenals were removed, the RNA extracted using cold phenol and the extracts subjected to polyacrylamide gel electrophoresis at 4° C. The gels were then stained with methylene blue and photographed for record.

Comparison of the gels indicated no differences between groups and/or sexes. It is thus concluded that RNA output is similar in each case. Work is now progressing on enzyme forms that may be present in the adrenal cells.

Stabilization of Lung Compliance in Rabbits During Natural and Artificial Respiration. THOMAS A. LESH and ANTHONY R. DOWELL, Department of Physiology and Health Science and Center for Medical Education, Ball State University, Muncie, Indiana 47306.——The "sigh" reflex in mammals periodically provides a brief hyperinflation which reopens collapsed alveoli and prevents undue decreases in lung compliance (Bartlett, D., 1971. *Respiration Physiology* 12:230-238). We made a quantitative study of this effect in New Zealand White rabbits, pretreated with acepromazine and anesthetized with sodium pentobarbital. In 15 measurements on 5 spontaneously breathing animals, a single "sigh" increased lung compliance by 6.6 ± 5.8 (SD) per cent; this change was significant ($P < .001$ by Student's t-test). The interval between sighs was 11.3 ± 2.5 (SD) minutes. Sighing could be suppressed by deepening anesthesia and applying intermittent positive-pressure ventilation (IPPV) at a rate sufficient to override spontaneous respiratory efforts. In 10 trials, compliance had fallen by 20.3 ± 12.9 (SD) per cent after one-half hour of IPPV ($P < .005$). An artificially induced mild hyperinflation of the lungs for one respiratory cycle raised compliance markedly but not always fully to the control value. Compliance rose further upon repeated hyperinflations or simply a return to spontaneous respiration.

Blood Pressure Studies Following Unilateral Ureteral Ligation in Rats. W. J. EVERSOLE, Indiana State University, Terre Haute, Indiana 47809.——The results of this study demonstrate that severance or ligation of the right ureter leads to increases in blood pressure in rats drinking 1% saline. The pressure is elevated at three weeks following operation and rises thereafter reaching a mean in some groups in excess of 200mm Hg by seven weeks. Ligation of the ureter approximately 3 centimeters from the hilum results in a greater rise in pressure than ligation near the hilum. Severance of the right ureter distant from the hilum also leads to extremely high pressures. Proximal to the ligation or severance point there is accumulation of fluid and eventual complete degeneration of the right kidney. Injection of fluid obtained from the degenerate renal pocket usually causes a rise in blood pressure in intact test animals, leading us to postulate the presence of a hypertensive agent in the accumulated fluid. Hypertensive animals have enlarged hearts and kidneys and in some cases the left kidney is grossly diseased.

Effects of an Unknown Factor on the Development of Adrenal Regeneration Hypertension. C. L. DEMAIO and W. J. EVERSOLE, Indiana State University, Terre Haute, Indiana 47809.——Rats derived from the Charles River strain were subjected to operative procedures which usually lead to the development of cardiovascular hypertensive disease within 5 weeks. One hundred seven rats were used in this study and were treated as follows: (I) right adrenalectomy; (II) right adrenalectomy, left adrenal enucleation; (III) right adrenalectomy, left adrenal enucleation, and right partial nephrectomy; (IV) right adrenalectomy, left adrenal enucleation and right nephrectomy; (V) right adrenalectomy, left adrenal enucleation, right nephrectomy and left partial nephrectomy. Following the operation most animals exhibited poor appetite, lassitude, muscular weakness and reduced weight gain. The mortality was excessive and correlated with the severity of the operation. The per cent surviving seven weeks in each group was 83, 83, 62, 29, and 11 respectively. In prior experiments the survival, regardless of type of operation, was over 98%. Animals in group IV were expected to gain weight at a near normal rate and at least 80% of them should have been hypertensive (BP>149mmHg), exhibiting enlarged kidneys and hearts at seven weeks post operative. However, 70% of the animals in this group died and 80% of the survivors had normal blood pressures but their hearts were enlarged. Four survivors in Group V exhibited a mean pressure of 169 mmHg and their hearts and kidneys were larger than those in other groups. It therefore appears that these animals suffered from a nutritional deficiency although the possibility of a latent infection has not been ruled out.

Effect of Aminoglutethimide on Rabbit EKG and Blood Pressures. MERVIN C. YODER and WILLIAM J. BRETT, Indiana State University, Terre Haute, Indiana 47809.——This study was conducted to determine if aminoglutethimide (AG) is acting on the sympathetic and/or vagal regulation of the rabbit heart to produce changes in blood pressure and heart rate. The right femoral and right common carotid arteries were exposed and cannulated in sodium pentobarbital anesthetized female rabbits to obtain direct systemic and intraventricular blood pressure. Heart rate was continuously monitored along with these pressures.

Intravenous (IV) sodium pentobarbital administration resulted in significant increases in heart rate. Lighter rabbits required higher doses of pentobarbital to reach level 3 anesthesia and consequently had significantly greater increases in heart rate than heavier rabbits. A 50 mg/kg IV injection of AG produced significant parallel reductions in mean systemic and mean intraventricular blood pressures which were dependent on the rate of AG injection. Heart rate decreases were variable but significant when compared to the results of control injection of distilled water. Blockage of beta adrenergic, alpha adrenergic, and cholinergic receptors with propranolol, phenoxybenzamine, and atropine methyl bromide, respectively, did not significantly change the effect of AG on blood pressure and heart rate even though atropine and propranolol significantly decreased heart rate and phenoxybenzamine significantly decreased blood pressure prior to AG injection.

There was no significant difference in the relationship between percent decrease in mean systemic blood pressure and rate of AG injection between blocked and non-blocked rabbits. Heart rate changes were variable and significantly decreased. These results suggest that AG does not act on the sympathetic and/or vagal regulation of the rabbit heart to produce decreases in blood pressure and heart rate.

Evidence for Acetylation of Aminoglutethimide by the Rat Liver. VICKY M. WELLS and WILLIAM J. BRETT, Indiana State University, Terre Haute, Indiana 47809.——The liver and kidney of certain vertebrates have been demonstrated to function in the excretion of Aminoglutethimide (AG). This study was conducted to determine whether AG is acetylated prior to excretion.

AG and "related" compounds from rat feces and urine were extracted in methylene chloride. The extracts were run against AG and acetylated AG standards by use of thin layer chromatography and spot location was procured by viewing under visible and U.V. light. Rf values for compounds from both urine and feces suggest the presence of AG and acetylated AG. Rat liver homogenate incubated with AG and sodium acetate also demonstrated similar thin layer spots.

Mestranol Receptor-Sites as a Relationship to Altered Cell Free Proteins. GREGORY E. CAPLINGER, PETE RIDLON, and LARRY GANION, Department of Physiology and Health Science, Ball State University, Muncie, Indiana.——It was reported by Caplinger *et al.* that the use of mestranol in varying quantities caused a subsequent alteration in the ovarian synthesis of cell free proteins. Where normal dose concentrations were employed there appeared to be a deletion of amino acid residues from the cell free proteins synthesized. This was thought to be an inhibition taking place in the ovary due possibly to an over saturation of the receptor-sites involved. If this were the case then the receptor-site assay would be lower in the fraction bound as compared to the lower concentration of mestranol. This was the case in the ovary. The relative numbers of mestranol receptor-sites was lower than the other concentration of mestranol used. The receptor assays of the groups where lower quantities of mestranol were employed was much higher which shows evidence for the proposed catalysis and addition of amino acid residues to the cell free proteins assayed. Thus one can conclusively see that mestranol and in all probability many other estrogens and other hormonal compounds have the chemical ability to effect receptor-sites which will then have a subsequent affect on protein synthesis and the entire metabolic pattern.

Localization of Mestranol Receptor-Sites in the Ovary. GREGORY E. CAPLINGER and LARRY GANION, Department of Physiology and Health Science, Ball State University, Muncie, Indiana 47306.——Within the past two years there has been much interest in the localization of hormonal receptor-sites and the subsequent role they play in regulating the metabolism of the organ involved. It was recently reported that many of the estrogenic compounds main receptor-sites were found in the uterus as would be expected since the so called target organ of estrogen is the uterus. It was also found that there are two specific receptor-sites within a particular cell. There is a cytosol receptor of which most of the hormone has been found located within the nuclear bound fraction. However this work by O'Malley (1971) and Gorski (1971) dealt with a physiological system in a normal state of equilibrium. Our concern was basically with a primed system as one would normally find in the case of an administered estrogen therapy program. In this state our results were conclusive and in opposition to previously reported data. There were distinct receptor-sites located in all organs assayed which included the uterus, ovary, pituitary, and liver. The majority of the bound mestranol was localized in the uterus with a relatively high bound fraction occurring within the ovary. Of the ovarian bound fraction most occurred in the nuclear fraction. This nuclear bound fraction would account for the abnormal alteration of ovarian cell free proteins by Caplinger *et al.* (1974). In conclusion these results of mestranol receptor-sites in the ovary support the previously published data by Caplinger *et al.* that point to altered ovarian cell free proteins as a result of mestranol treatment. Thus the interaction of mestranol, receptor-site, and subsequent metabolism are dependent upon the preexisting use of mestranol and the concentration used. Also as one can see this alteration will inevitably affect ovarian metabolism and synthesis of proteins.

An Electron Microscope and Autoradiographic Study on the Formation of the Zona Pellucida in the Prepubertal Mouse Ovary. LARRY R. GANION, Department of Physiology and Health Science, Ball State University, Muncie, Indiana 47306.——Ovaries from 1- to 21-day-old mice were fixed in 3% glutaraldehyde, post-fixed in 1% osmium tetroxide, embedded in epon 812, and viewed in an RCA EMU 3-C electron microscope. Zona pellucida development began in unilaminar ovarian follicles. Small clefts were initially observed between the oocyte and follicular envelope. These clefts subsequently became filled with a granular-fibrillar material and fused to form a continuous layer around the egg. During this time, elements of rough endoplasmic reticulum were observed within the ovarian follicle complex and were especially numerous within follicle cells. Profiles of vesicular and saccular Golgi were commonly encountered in the developing follicles. Moreover, many large vesicles were observed in the corticle ooplasm, some appearing to fuse with the oolemma. Preliminary histochemical studies suggested that the mouse zona pellucida is composed of a carbohydrate-protein complex. To investigate synthetic activities at the time of zona pellucida formation, prepubertal mouse ovaries were cultured *in vivo* with either glucose–^{3}H or leucine–^{3}H and prepared for light microscope autoradiography. Both isotopes were readily incorporated by the developing follicles. In each instance, after one day the label was generally distributed over the ovarian tissue and numerous silver grains appeared over the oocytes. With time the oocytes became extensively labeled and in some follicles, grains occurred over the zona pellucida. These observations will be discussed with respect to the origin of the zona pellucida.

A Scanning Electron Microscope Study of Female *Androlaelaps fahrenholzi* (Acarina:Laelapidae) from the Woodchuck, *Marmota monax*. REBECCA J. GOFF and JOHN O. WHITAKER, JR., Department of Life Sciences, Indiana State University, Terre Haute, Indiana 47809.——*Androlaelaps fahrenholzi* has been reported from 118 mammal species over a geographic range of 54 states and Canadian provinces in North America (Whitaker, J. O., Jr. and N. Wilson, Amer. Midl. Natur. 91:1; 1974). Its morphological variability between hosts has led several authors to consider *A. fahrenholzi* a complex of closely related species. Due to its increased surface resolution, a scanning electron microscope (SEM) study was undertaken in an effort to identify fine structural features not easily resolvable under the light microscope that might prove valuable in classification. Examination with the SEM revealed that: (1) anal aciculae of uniform length are oriented anteriorly and arranged in rows at the base of the anal plate; (2) the stigmal pore contains randomly grouped projections and the peritreme is lined with fine peg-like structures; (3) the tritosternal pili and deutosternal denticles do engage; and (4) rows of tiny projections extend into the pre-oral groove in close association with the sensillae of the labrum. It is hoped that similar comparative studies of *A. fahrenholzi* from different hosts will aid in determining whether these forms should properly be considered as *A. fahrenholzi*, or whether some should be recognized as separate species.

The Social Behavior of a Group of Holstein-Friesian Milking Cows. JAMES C. WILSON, Hawkesbury Agricultural College, Richmond N.S.W. 2753 Australia and J. L. ALBRIGHT, Department of Animal Sciences, Purdue University, West Lafayette, Indiana 47907.——A milking group of 16 Holstein-Friesian cows housed in a free stall barn at the Purdue University Dairy Center was observed over a period of four weeks in the spring of 1975.

Four of the cows were added to the previously stable group of twelve early in the observation period. The average age of the group was between six and seven years. It was part of a long-term urea feeding trial which keeps the group isolated over many years. The introduction of new cows to the group did not cause the upheaval expected. None of the introductions had been part of the group before.

All behavior which could possibly have social implications was recorded and an attempt was made to interpret it. Criteria for the more complex types of behavior were established with the aid of the literature reviewed and previous experience.

Both quantitative and qualitative data revealed a wide variety of behavior as probably having social implications. There were no readily distinguishable categories or social types into which the majority of the cows fell automatically. Some low ranking cows in the social order were far more aggressive than some cows that dominated them when interactions occurred.

Attention was also drawn to the complex and subtle nature of interactions and inter-cow communication in a group of cows forced to live at close quarters for long periods of time. Tolerance of conspecies in close proximity or actual body contact was notable.

Some of the variation from a predicted response was interpreted as being due either to a variation of intensity of the releasing stimulus or the intensity or manner in which the stimulus was received by the other cow. In other words, the intensity of a releasing situation depends on a number of variables in more than one animal.

One conclusion is that individual personalities of cows fall automatically into no watertight compartments, nor are they always instantly or easily recognized or deciphered. Nevertheless, their social disposition is seen as the clearest measure of their temperament or personality. Non-interaction itself is also seen as a temperament trait. The claim made by some researchers that the social order of a group of dairy cattle can be established after a full single day's observation cannot be sustained as far as this particular group of cows is concerned.

Diets of sympatric *Acris crepitans* and juvenile *Bufo woodhousei fowleri* in western Indiana. GEORGE M. LABANICK, Department of Zoology, Southern Illinois University, Carbondale, Illinois 62901 and RAYMOND A. SCHLUETER, Division of Science and Mathematics, University of Tampa, Tampa, Florida 33606.——Feeding competition between sympatric *Acris crepitans* and juvenile *Bufo woodhousei fowleri* was slight. *Bufo w. fowleri* exploited ground-dwelling ants whereas *A. crepitans* utilized a diversity of ground and above ground-dwelling prey.

Nesting Studies of the Indigo Bunting *(Passerina cyanea)* at Thornhill, Indiana

FRED D. MORGAN
Department of Biology
Huntington College, Huntington, Indiana 46750

Abstract

Two all-day observations were made of a nest of the Indigo Bunting during the incubating period and when young were in the nest. Only the female was observed incubating the eggs, brooding, and feeding the young. Incubating constancy was determined to be 79.4%. Weights of 9 eggs ranged from 1.68 to 2.40 g with a standard deviation of 0.25 and a mean of 2.09. Weight loss of 5 eggs during the incubating period ranged from 12.7 to 17.9% with a mean of 15.8. The earliest nest was found with 3 eggs on 11 June and the latest egg in a clutch of 3 was laid 9 August. The incubating period was determined to be approximately 12 days and the nestling period 8 to 9 days. Weights of 5 nestlings were taken daily at 24-hour intervals. Out of 7 nests 5 were parasitized by the Brown-headed Cowbird and all 5 parasitized nests were subsequently deserted. Nesting success was calculated to be 22.5%. Location, nest measurements, and construction of nests are discussed. Nesting height of 7 nests ranged from 33.0 to 110.5 cm with a mean of 62.1.

Introduction

Seven nests of the indigo Bunting were observed during a study conducted on a farm of 31.6 ha owned by Huntington College. The research involved all the nesting species on the farm but enough information was gleaned on this species so that a limited report was thought feasible. The farm is located about 11.3 km directly north of Huntington, Indiana. Five summers (1964-67; 1973-74) were encompassed in the study. Conditions for nesting appeared to be ideal along the margins of woodland areas and open fields going through a successional state. Few nests were actually found though the area was searched diligently.

Materials and Methods

A portable blind was used for making nesting observations. Binoculars (× 50) and a spotting scope (20X and 40X) were available for close-up monitoring. For the taking of weights in the field a dial-o-gram Ohaus scale was utilized. Weights to the nearest hundredth of a gram were possible. The scales were permanently mounted in a small wooden box with a sliding glass window. A leveling bubble was used for the rough field conditions.

Weights of freshly laid eggs were made. The eggs were marked sequentially when weighed on the days that laying occurred. When weights were obtained on freshly laid eggs, the weights of these eggs were also taken the day before hatching to determine weight loss during the incubating period. Upon hatching the feet of the young birds were marked and weights taken daily at a specified time period until the young fledged from the nest.

Results

Nesting Observations.—An all-day observation was made of a nest 11 August, 2 days after the last egg of a clutch of 3 had been laid. The cloud cover was broken with temperatures in the area ranging from 17.2° to 33.8° C at 1 m above the ground. The observation began at 05:00 and ended at 20:15. The female left the nest for the first time at 06:13 and was on the nest for the night at 19:23. Her active portion of the day totaled 13 hr and 10 min. Only the female did the incubating although the male was frequently near. He was heard singing several times in nearby trees throughout the day. The longest attentive period on the nest was 106 min and the shortest 22. The longest inattentive period was 25 min and the shortest 7. The average of 14 attentive sessions was 44.8 min; the average of 15 inattentive sessions was 10.9 min. The total incubating time was 10 hr and 27 min for an incubating constancy of 79.4%.

Forbush (7) relates that the male is reported to relieve the incubating female on the nest. My observations at Thornhill would tend to discount any such generalization. The all-day observation plus daily visits to the nest always found the female alone incubating the eggs. Another nest which was visited frequently indicated that only the female was performing the task of incubation. Bradley (4), Allen (1), Sutton (11), and Bent (3) report that only the female does the incubating.

This same nest was under an all-day observation again on 20 August. The sky was mostly cloudy with temperatures ranging from 16.1° C to 32.2° C at 1 m above the ground. The day of observation began at 05:15 and ended at 20:00. The status of the nest was checked at 05:45 when the female left the nest. Two eggs had hatched and 1 was still in the nest. The remaining egg hatched about 07:40 at which time the brooding female hopped onto the edge of the nest. She then took half of the egg shell and rotated the shell in her bill as she ate it. The female picked up the remaining half and consumed it also. Then she settled back on the nest to continue brooding. The active day at the nest extended from 05:45 to 19:48 or 14 hr and 3 min. During this time the female brooded for 6 hr and 9 min for a total of 43.7% of the active day. Of 37 brooding periods the longest was 27 min and the shortest being 1 with a mean of 9.97. Of 38 periods off the nest the longest was 27 min and the shortest 3 with a mean of 12.47. The female fed the young 54 times during her active day for an average feeding interval of 15.56 min. The food consisted of insects, larval forms, and small berry-like fruit. Fecal sacs of the young were removed from the nest 3 times and eaten 9 times.

The male did not feed the young during the day of observation. He was observed escorting his mate a few times when she left to feed and was with her on one occasion when she returned to the nest. Bent (3) cites evidence that the male feeds the young. Bailey (2) obtained stills and movies of the male feeding the nestlings. Bradley (4), however, observed no feeding of the nestlings or fledglings by the male. Sutton (11) indicates that the male may take complete charge of the fledglings while the female proceeds with a second nesting.

Eggs.—Two nests contained 3 eggs each. Another nest held 3 bunting eggs and 1 Brown-headed Cowbird's (*Molothrus ater*) egg when first discovered. Four other parasitized nests were *deserted before* clutch size was attained. Bent (3) gives evidence of clutches varying between 2 and 4 eggs. Phillips (10) observed 6 nests which demonstrated an average clutch size of 3.3 eggs. Trautman (12) records that of 16 nests examined at Buckeye Lake 5 contained 3 eggs or young each; 3 parasitized nests held 3 eggs or young of the host and a cowbird's egg or young each; 6 demonstrated 4 eggs or young each; and 2 parasitized nests disclosed 4 eggs or young of the host and a cowbird's egg or young each. Bradley (4) found 2 nests with 4 eggs and 2 nests with 3 eggs.

Nine eggs were weighed on the day they were deposited in the nest and ranged from 1.68 to 2.40 g with a standard deviation of 0.25 and a mean of 2.09. Holcomb (8) reports the weights of 7 eggs, weighed the day following the laying of the final egg, as ranging from 1.5 to 2.3 g with a mean of 1.89. Weight loss of 5 eggs during the incubating period ranged from 12.7 to 17.9% with a mean of 15.8.

The earliest active nest was found with 3 eggs on 11 June and the latest egg in a clutch of 3 was laid 9 August. In 1966 and 1967 there was evidence that 2 nesting attempts were made in the same territory as the first nest in each instance was located close to a second nest. In 1966 the first nest was deserted on 13 July and a second nest in the same territory was found under construction on 5 August. The first egg appeared in this nest on 7 August. In 1967 the first nest was deserted on 24 June and a second nest was found under construction about 20 m away on 10 July. In this latter nest the first egg appeared 13 July. Both of the early nests were parasitized by the Brown-headed Cowbird whereas the two later nests were not.

Incubating and Nestling Period.—One nest demonstrated an incubating period of nearly 11 days. In this nest the last egg appeared 9 August and hatched at about 07:40 on 20 August. This egg was probably laid early in the morning on 9 August making the incubating period extend just beyond an interval of 11 days. In a second nest the third and last egg did not hatch. However, the second egg in the clutch of 3 hatched in 12 days. Cleveland (5) observed a nest in which the last egg hatched in 12 days. Bent (3) cites evidence that indicates an incubating period of 12 to 13 days. Temperatures at the time of nesting probably hasten or slow down the development of the embryo thus shortening or lengthening the incubating period.

The nestling period is not too reliable because the young were weighed daily. One had no difficulty until the fear reaction began to develop about the sixth or seventh day. To avoid this problem of early fledging, I would cup my hand over the nest after returning the older nestlings from weighing. After the nestlings had settled in the nest and appeared calm, I slowly removed my cupped hand from over the nest and retreated. This process was successful with the Indigo Bunting as the young remained in the nest while I was present at the nesting site. The question still remains whether the handling of the young conditioned them to leave early. The nestling period ranged from 8 to 9 days for two successful nests at Thornhill. Cleveland (5) reported a nestling period of 9 days, Bradley (4) 7 to 9 days, and Allen (1) 10 days. Table 1 gives the weights of the young as taken at intervals of 24 hr after the initial weighing. The average gain in grams and the per cent of gain this represents are given respectively as follows: (1) 1.20-56.6% (2) 1.22-36.7% (3) 1.50-33.0% (4) 1.58-26.2% (5) 1.52-19.9% (6) 1.44-15.8% (7) 0.30-2.8% (8) 0.39-3.6%.

Parasitism and Nesting Success.—Five out of 7 nests or 71% were parasitized by the Brown-headed Cowbird. In each instance the parasitized nests were deserted. The 2 successful and nonparasitized nests were constructed in the latter part of July and first part of August after the cowbird's egg-laying activity had largely ceased.

The molestation of a particular nest is worthy of mention. In the early morning while taking a census, a female Indigo Bunting was noted in a certain locality. In the afternoon a search was made and the nest found about 14:00 on 22 June. There were 2 eggs of the bunting in the nest at the time of discovery. Upon returning to the nest at about 17:00 to mark the eggs, only 1 egg was found in the nest. Removal of the 1 egg by a female cowbird was inferred. Expecting a visit by the cowbird early the next morning, I hid in a blind before daybreak. Because of the darkness, I did not check to see if the second egg of the bunting was still in the nest before I climbed into the blind. At 05:02, 6 min before sunrise, a female cowbird was observed to approach the nest. In approximately 30 sec she left. Upon examining the nest immediately afterwards, a wet, warm cowbird's egg was observed in the nest. The second egg of the host was also missing from the nest.

Following Mayfield's (9) suggestions for calculating total nesting success a figure of 22.5% is obtained. On the basis of my studies at Thornhill the reproductive success of the bunting is greatly reduced through the parasitic activities of the Brown-headed Cowbird.

Location and construction of the Nest.—Nests were constructed in spicebush (*Lindera benzoin*), black walnut (*Juglans nigra*), sugar maple (*Acer saccharum*), black raspberry (*Rubus occidentalis*), blackberry (*Rubus allegheniensis*), and multiflora rose (*Rosa multiflora*). Shrubby growth along the edge of wooded areas seemed to be preferred. Measurements of the 7 nests yielded the following: (1) the outside

TABLE 1. *Growth in Grams of Nestling Indigo Buntings.*

Days After Hatching	0	1	2	3	4	5	6	7	8
1966-Plot #2	2.34	3.60	4.98	6.73	7.86	9.30	10.57	10.59	
Nest #2	2.07	3.19	4.44	6.18	8.16	9.58	11.08	10.90	10.67
	1.81	2.51	3.58	5.14	6.71	8.48	10.06	10.63	10.30
1967-Plot #2	2.24	3.66	4.95	6.43	7.95	9.15	10.58	10.82	
Nest #2	2.12	3.62	4.76	5.74	7.42	9.19	10.62	11.48	
Total Weight	10.58	16.58	22.71	30.22	38.10	45.70	52.91	54.42	20.97
Average Weight	2.12	3.32	4.54	6.04	7.62	9.14	10.58	10.88	10.49
No. of Birds	5	5	5	5	5	5	5	5	2

distance from the bottom of the nest to the top edge—7.49cm, (2) the inside depth—3.86 cm, (3) the inside diameter—5.09 cm × 5.40 cm, and (4) the outside diameter—8.81 cm × 9.35 cm.

Two nests were collected and studied in relationship to their fabrication. The bases and outer bowls of both nests contained mostly leaves which were held together primarily with the leaves of coarse grass. One nest contained a piece of soft plastic. The leaves used were small, soft and well-weathered with much of the inner venation exposed. The inner bowl was formed almost exclusively of fine grass stems. Small bits of webbing, thistle down, and cat-tail down were present. An upright crotch was used in the small trees with strippings woven around the rather small limbs to help anchor the nest in place. In the thorn bushes the nest was largely suspended by plant fibers woven around the stems. Being built close to the ground the nests were protected from strong winds and withstood storms well. One nest was still intact after passing through a winter season.

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A Range Extension of *Peropteryx Kappleri* (Family Emballonuridae) in Central America

Anne M. Cartwright and Ralph D. Kirkpatrick
Biology Department
Ball State University, Muncie, Indiana 47306

A greater doglike bat, *Peropteryx kappleri,* was collected 28 June 1976 in a cave near Rio Frio Cave approximately 0.8 km north of Augustine, Cayo District, Belize, latitude 16°58′ N. Associated bat species taken at the same time from the same cave include Thomas' sac-winged bat, *Balantiopteryx io,* and the vampire, *Desmodus rotundus.* Taken on the same date from a cave approximately 100 m west was Parnell's mustache bat, *Pteronotus parnellii.* Pallas' long-tongued bat, *Glossophaga soricina,* and *B. io* were taken from these two caves in previous years (1972, 1973, and 1975).

The single specimen of *P. kappleri* (AMC #133) is a female that is not pergnant or lactating. Body measurements (mm) taken after preservation as an alcoholic in AFA are TL 64-T 14-HF 10-E 15-Tr 7-Fa 49=? Wt.

The collection of this first record of the species for Belize extends the known range approximately 96 km north of the supposed Belizian range indicated by Hall and Kelson (1959). Specimen records from adjoining countries include Guatemala (Sanborn 1937, Goodman 1942) and Mexico (Dalquest and Hall 1949, Villa-R. 1966).

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Seasonal Changes in Soil Arthropod Species Diversity as Affected by Perturbation in Three Successional Communities in Northeastern Indiana

JAMES D. HADDOCK and N. DAVID SCHMIDT[1]
Department of Biology
Indiana University-Purdue University at Fort Wayne
Fort Wayne, Indiana 46805

Abstract

The effects of perturbation due to a long-term pesticide on seasonal changes in arthropod species diversity were studied on three successional communities: an oldfield, blackberry bramble and woodlot sites. Treatment plots received one application of chlordane using the recommended dosage in early May, and samples from control and treatment areas were collected and processed from mid-May biweekly until early December. Total arthropod diversity was highest in the blackberry zone. The oldfield and blackberry communities exhibited slightly less stability than the woodlot as indicated by oscillation in the recovery pattern and overall repression of species diversity in the treatment plots. With respect to the variety and evenness components of overall species diversity, neither exhibited a significant difference in the treatment versus control plots in the oldfield. In the blackberry site a significant difference was obtained in variety only. The evenness index of the woodlot exhibited a significant difference in the treatment and control plots over the last half of the sampling season.

Introduction

The effects of perturbation or stress on species diversity in successional terrestrial and aquatic communities has been a natural consequence stemming from the interest generated by MacArthur (6), Margalef (8) Hairston et al. (2) and many others in the field of ecosystem stability and diversity as it relates to community development.

Several authors including Barrett (1), Malone (7) and Shure (13) have investigated the effects of a short-term pesticide on the stability of oldfield ecosystems. Hurd et al. (3) studied the influence of soil enrichment by fertilization on abandoned hayfields. An excellent review of insect stability and diversity in agro-ecosystems is provided by van Emden and Williams (15). Tramer (14) has reported on the regulation of plant species diversity on an early successional oldfield.

The present study was designed to test the effects of a persistent pesticide, chlordane, on the seasonal diversity patterns of terrestrial arthropods in three successional terrestrial communities over a period of one year.

Study Area and Methods

This study was conducted on research property comprising approximately 6 hectares adjacent to the Indiana University-Purdue University at Fort Wayne Campus in Allen Co. Indiana. The three communities investigated were an abandoned oldfield, a blackberry bramble site and a mixed oak woodlot. The soil type is silt loam. The oldfield has been undisturbed since 1970 and the producer trophic level is composed of herbaceous perennials. Species of aster, daisy and goldenrod are typical of the broad leaved plants and timothy, orchardgrass, smooth brome and Kentucky bluegrass are the most important grasses. The blackberry bramble plot derives its character from species of wild blackberry and feral roses. It also has herbaceous species found in the oldfield and woody species such as box elder found on the third site, the woodlot. The blackberry bramble site has been undisturbed for at least 15 years. Red oak is the dominant overstory tree found in the woodlot and sugar maple dominates the sapling class.

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[1] Present address: Harley Feed and Fertilizer, Inc., Chambers, NE 68725.

Control and treatment plots each measuring 3.05 by 4.57 meters were established in the three zones. Two weeks prior to the first sampling date (mid May) each treatment plot received one application of a chlorinated hydrocarbon pesticide, chlordane, with a hand-carried sprayer. Application was at the recommended rate of ¼ pint per 46.5 sq. meters. Chlordane was used because of its high toxicity and persistence (Nash and Woolson, 10). Each treatment plot was sprayed only once during the 1975 season. Soil arthropods were collected by combining three subsamples each of which measured 5.0 by 7.5 cm. by use of a soil corer. Samples were taken every other week in control and treatment plots in each zone from mid-May to early December. Soil arthropods were processed through Berlese funnels and organisms collected were sorted to species and preserved in alcohol or on permanent slides.

Soil temperature was measured at the surface and at depths of 2.5 cm. and 7.6 cm. depths in the soil. Accumulative soil moisture measurements were determined at 2.5 cm. and 7.6 cm. depths after comparing wet and dry weights. Physical measurements were taken between 12 noon and 2 PM. Soil respiration was measured over a 24 hr. period using KOH absorption (Lundegardh 5, Kucera and Kirkham 4).

Physical Factors

A detailed statistical analysis of soil temperature, moisture and CO_2 evolution is reported in an adjoining paper and need only be summarized here. The woodlot exhibited a significantly lower temperature (Fig. 1) than the oldfield and blackberry zones at the 2.5 cm. depth as might be expected due to differences in density of vegetation. Soil temperatures exhibited a gradual increase that peaked in August and decreased abruptly in September. Soil moisture measurements from the woodlot were significantly higher than those of the other two zones due to the buffering effect of the overhanging vegetation and litter (Fig. 2). Soil moisture data at the 2.5 cm. levels in the oldfield exhibited no significant difference from that of the blackberry zone when compared over the entire season. The oldfield sustained a great increase in soil moisture during the month of June which accentuated the effect of the chlordane in the treatment plot. All three communities showed a decrease in soil moisture in July and August.

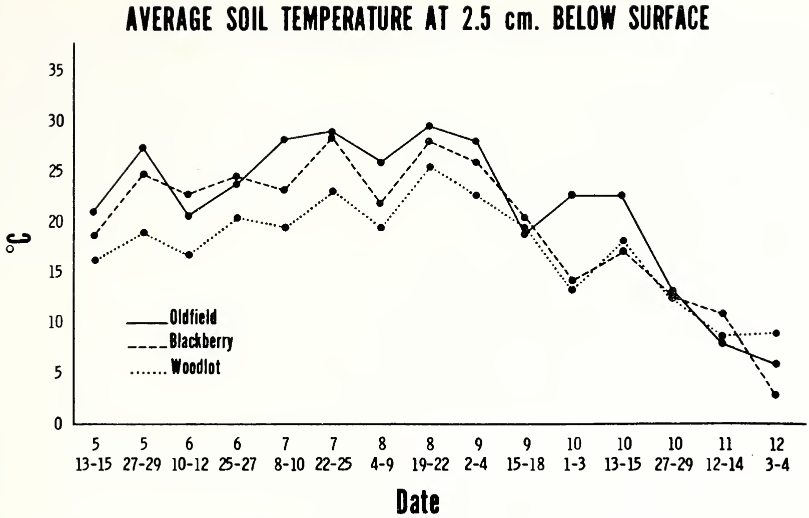

FIGURE 1. *Seasonal patterns in soil temperature at the 2.5 cm. depth in the oldfield, blackberry, and woodlot communities.*

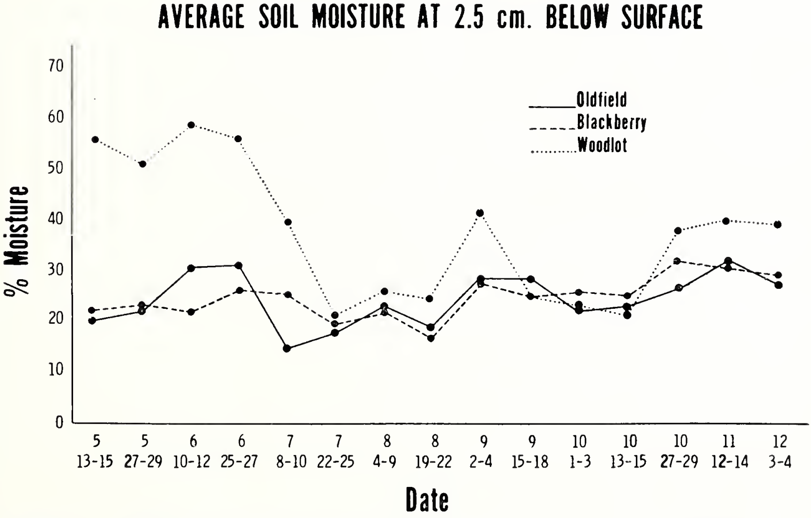

FIGURE. 2. *Seasonal patterns in soil moisture at the 2.5 cm. depth in the oldfield, blackberry, and woodlot communities.*

Seasonal Diversity Patterns

Species diversity as indicated by the Shannon Index, $\overline{H}$, (Shannon and Weaver, 12) when plotted over the entire season was significantly higher in the blackberry control zone than it was in either the oldfield or woodlot control areas (Fig. 3). Diversity values for the oldfield and woodlot controls were not significantly different from each other.

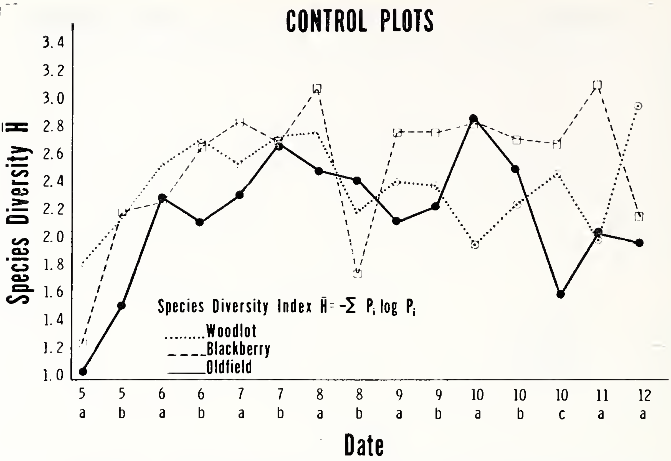

FIGURE 3. *Seasonal patterns in soil arthropod species diversity, H, in control plots of the oldfield, blackberry, and woodlot communities.*

All three control plots showed increased diversity throughout the early growing season as might be expected. The fluctuation in the blackberry control in late August was due to an abnormally large number of ants encountered.

Perturbation had its greatest effect in the blackberry zone (Fig. 4) as the treated area never fully recovered from the pesticide stress. The diversity index was broken down into its two components: Variety

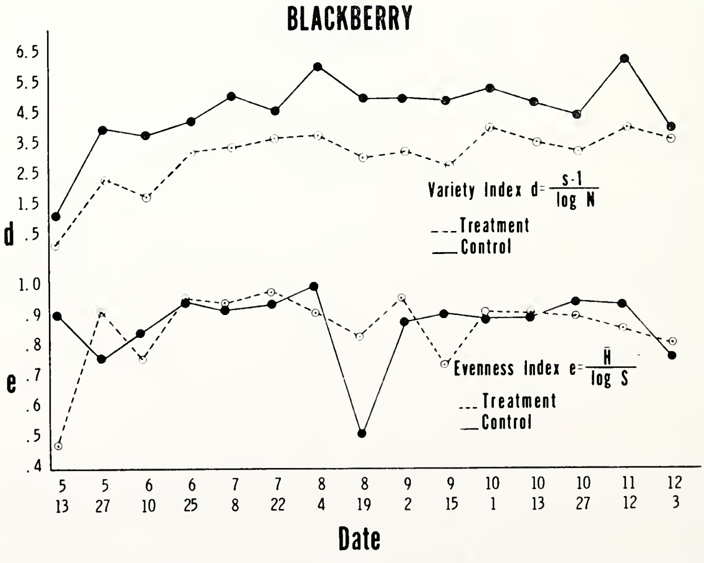

FIGURE 4. *Variety, d, and evenness, e, components of soil arthropod species diversity for control and treatment plots in the blackberry community.*

$(d = \frac{S-1}{\log N})$ and evenness of individuals among the species $(e = \frac{H}{\log S})$ where S = number of species (Pielow, 11) and applied to each of the three successional sites. The blackberry stage showed a significant difference in the treatment and control plots with respect to the variety component only. The difference in diversity between the two plots is primarily due to the very high loss of "macro" predators from the experimental area (Fig. 5).

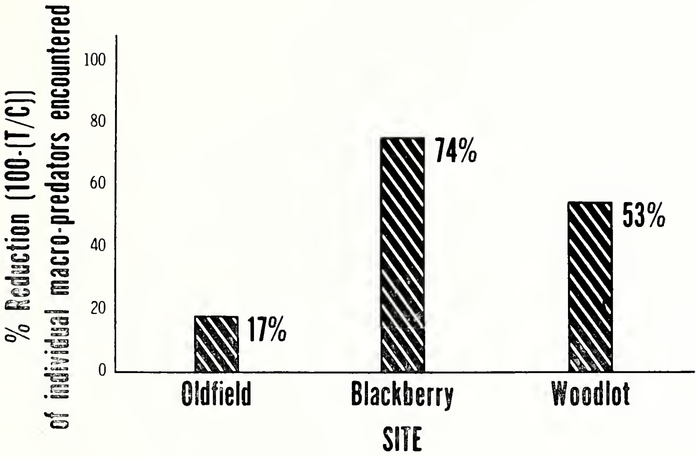

FIGURE 5. *Percentage reduction of individual predators due to perturbation by chlordane in three northeastern Indiana communities.*

Results in the oldfield show that what appeared to be recovery from insecticidal stress took place in May and early June with some treatment "overshoot" occurring (Fig. 6). In June, however, rainfall probably carried the pesticide into the 2.5-7.5 cm. zones of the soil which markedly affected diversity until late August. The blackberry and woodlot zones displayed similar but less profound reactions in late May. The oldfield showed only a 17% loss in "macro" predators over the season (Fig. 5) in addition to having only about a third as many predators as was found in each of the other two study sites.

The woodlot community exhibited a significant difference in the evenness component but for only the last half of the sampling season (Fig. 7). It is probable that the effect of the chlordane may have been repressed until it had fully passed through the upper layers of the litter zone and then affected only small percentages of different arthropod species.

Summary

Total arthropod diversity was highest in the blackberry community. In the blackberry site a significant difference between the treatment and control was obtained only in the variety component. With respect

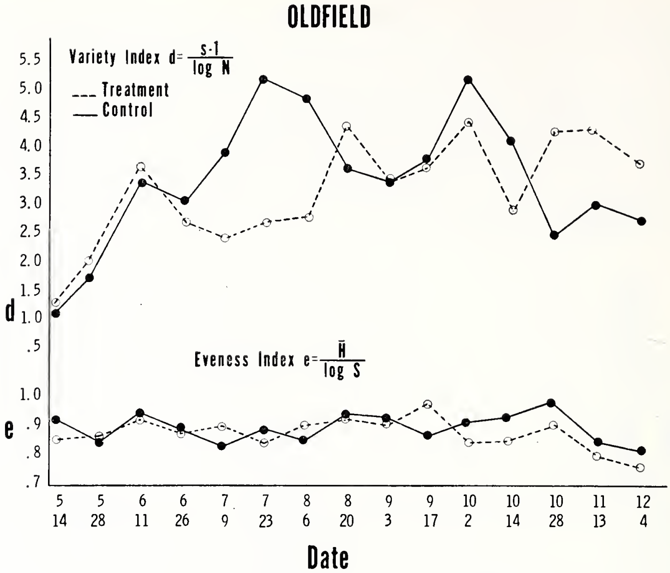

FIGURE 6. *Variety, d, and evenness, e, components of soil arthropod species diversity for control and treatment plots in the oldfield community.*

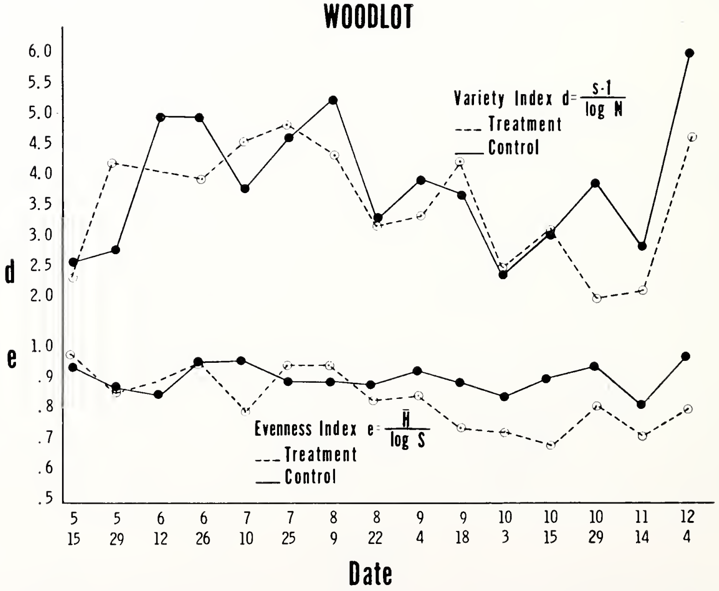

FIGURE 7. *Variety, d, and evenness, e, components of soil arthropod species diversity for control and treatment plots in the woodlot community.*

to the variety and evenness components of overall species diversity in the oldfield, neither exhibited a significant difference in the treatment versus control plots. The evenness index of the woodlot exhibited a significant difference in the treatment and control plots over the last half of the sampling season.

A definition of stability as advanced by Hurd et al. (3) (after May, 9) is that it is the ability of a system to maintain or return to its ground state after an external perturbation. This approach to stability is certainly operational and can be applied here. All three successional communities exhibited some lack of stability in that there was failure of the treatment zone to recuperate after being stressed (blackberry community) or extensive oscillation of the treatment throughout the sampling season as seen in the oldfield and to a lesser extent the woodlot.

Acknowledgments

Technical assistance was given by Bruce Keller and Ann Creselius. The graphs were prepared by Larry Wahli.

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Soil Environment and Respiration As Influenced by Secondary Succession and Chlordane On Three Northeast Indiana Sites

N. DAVID SCHMIDT[1], GERALD E. BENDIXEN[2], JAMES D. HADDOCK
Department of Biology
Indiana University-Purdue University at Fort Wayne
Fort Wayne, Indiana 46805

Abstract

The effects of chlordane and successional development on carbon dioxide evolution were studied on their northeastern Indiana sites during the 1975 growing season. Soil moisture, temperature, and carbon dioxide evolution were sampled every two weeks from mid-May to December on a control plot and a treated plot on each of the three sites. A multiple regression of the data removed the effects of soil moisture and temperature and determined the effect of chlordane on soil respiration. Chlordane reduced the level and natural variability of soil respiration measurements. These effects were more significant on the sites of early successional development.

Introduction

Soil respiration has been studied in a variety of ecosystems from at least as early as Lundegardh (1), (2). In this study the effects of succession and perturbation (chlordane) on soil carbon dioxide evolution were explored. An attempt was made to determine whether the effects are direct or if they are due to an alteration of the physical environment due to succession.

Methods and Materials

The dynamics of temperature, moisture, and carbon dioxide evolution were examined throughout the 1975 growing season in three northeast Indiana plant communities: a woodlot, a blackberry brambles and an old field. All sites were within .5 kilometers of each other. The soil texture on all sites was a silt loam and they all had a silty clay loam texture in their upper horizons. The woodlot and old field were situated on the Morley Series (Morley silt loam, 2-6% slopes, moderately eroded) and the blackberry brambles site belonged to the Martinsville Series (Martinsville silt loam, 0-2% slope).

The complete history of the woodlot is not known. Based on the size of the red oak (*Quercus rubra*) and basswood (*Tilia americana*) root sprout regeneration, the last extensive cutting probably took place some 30 to 40 years ago. Sugar maple (*Acer saccharum*) comprises most of the saplings and will eventually dominate if the site remains undisturbed. The old field site has not been farmed in the last four years and herbaceous perennials are dominant. Important grasses include orchard grass (*Dactylis glomerata*), Kentucky bluegrass (*Poa pratensis*) and timothy (*Phleum pratense*). The dominant forbs are mainly composites belonging to the genera *Erigeron*, *Aster*, and

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[1] Present Address: Harley Feed and Fertilizer, Inc., Chambers, NE 68725.

[2] Department of Mathematical Sciences.

Solidago. Species of *Rosa* and *Rubus* are responsible for the character of the blackberry bramble site. Many of the herbaceous species found in the old field are present but the forbs are much more abundant than the grasses.

Sampling was conducted at approximately two week intervals starting in mid-May. The sites were sampled on sequential days with the blackberry site being first and the woodlot last. Three soil cores were taken of the top one inch and three cores of the top three inches for soil moisture determination. Triplicate temperature readings were taken at the soil surface, one inch depth and three inch depth at each sampling time. The soils were dried to constant weight at 105°C and percent moisture on a dry weight basis was determined.

In early May, at each site, one of a pair of 3 by 4.5 meter plots was sprayed with chlordane according to the label instructions. CO_2 evolution was determined by absorption by a base (20 ml of 1.000N KOH) and subsequent titration with HCl. The chambers were one gallon cans painted white. Three determinations were made on each of the treatment and control plots at each site at each sample time.

A preliminary study showed that the soil moisture at the 3 inch depth and the temperature at the 1 inch depth were more closely associated with the changing values of CO_2 evolution. Therefore, only the soil moisture and temperature at these depths were used in the subsequent analysis. To remove the dependence of soil respiration on moisture and temperature, a multiple regression was performed. Treating each of the three sites separately, the logarithm of CO_2 was regressed against soil moisture and the logarithm of temperature.

Results and Discussion

The average seasonal moisture, temperature and CO_2 evolution are shown for the various sites (Table 1).

TABLE 1. *Average values of measured variables at each site.*

	Moisture %		Temperature °C			CO_2 Evolution mg C/hr/m^2	
Site	1 inch	3 inch	Surface	1 inch	3 inch	Treated	Control
Oldfield	23.7	21.8	23.1	21.5	20.0	62.9	86.2
Blackberry	24.1	21.9	21.4	19.2	18.0	65.8	81.2
Woodlot	33.8	32.4	19.3	17.0	16.1	45.4	46.9

The results of the data collected at the oldfield site is shown in Figure 1. The horizontal axis indicates the day of the year (number of days since December 31, 1974) the sample was taken. Shown are two lines describing the measured CO_2 evolution on the control and treatment plots. Each of the data points on these curves is an average of the three values of CO_2 evolution observed at that sample time. The other two lines show the predicted values of CO_2 evolution at each sample time in each plot. The predicted values are based upon the

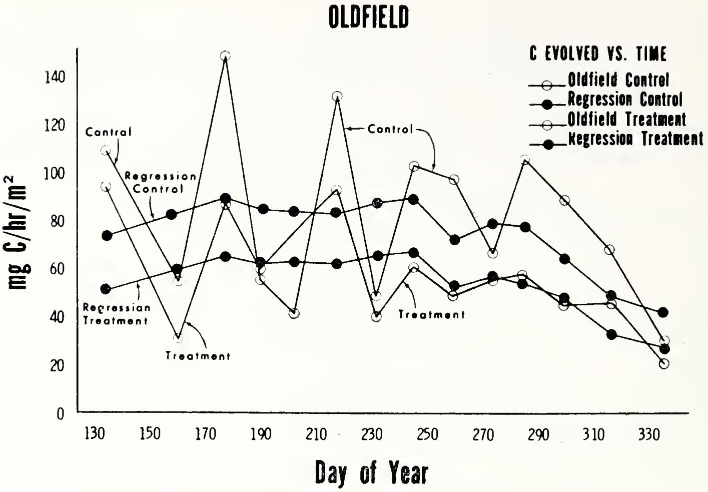

FIGURE 1. *CO_2 Evolution at Oldfield Site vs Day of Year.*

results of the multiple regression and vary according to the soil moisture and temperature at the sample time. The regression curve of the treatment plot is 27% lower ($p = .003$) than the regression curve of the control plot. One also can observe that the measured values of CO_2 evolution on the treated plot have lower peaks than the values from the control plot. Chlordane had the effect of reducing the natural variability in soil respiration.

Figure 2 shows the CO_2 measurements and the regression curves for the blackberry site. There was a 16% reduction ($p = .06$) in the

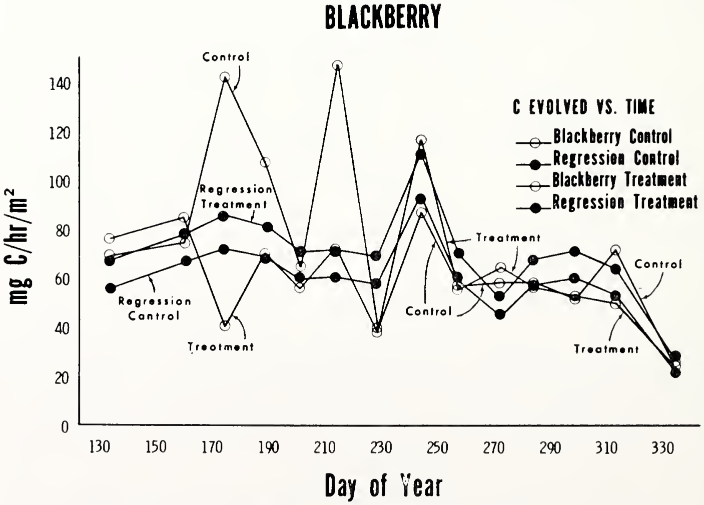

FIGURE 2. *CO_2 Evolution at Blackberry Site vs Day of Year.*

regression curve at the treated plot compared to the control plot. The natural swings in CO_2 evolution measurements appear to be reduced in the treated plot.

Figure 3 describes the observations on the woodlot site. The multiple regression indicated that there was no significant difference in the CO_2 evolution values at the two plots and therefore only one regression curve is shown. The CO_2 evolution measurements after correction for soil moisture and temperature are lower on the woodlot site than either of the other two sites. With respect to this observation, it may be mentioned that no attempt was made to equalize soil nutrients at the three sites.

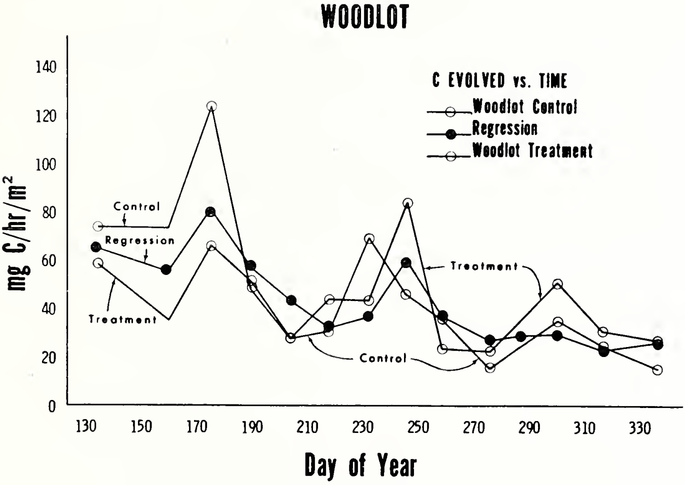

FIGURE 3. *CO_2 Evolution at Woodlot Site vs Day of Year.*

Summary

Significant differences in carbon dioxide evolution due to both successional development and treatment were found to exist during the 1975 growing season. The effect of chlordane was to reduce the level of carbon dioxide evolution and to reduce the natural variability of the measurements. In this study, both of these effects were more significant in sites of early successional development.

Acknowledgments

The authors appreciate the technical assistance provided by Bruce Keller and Ann Creselius.

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Ontogenetic Changes in Phototactic Behavior of *Ambystoma tigrinum tigrinum* (Amphibia: Urodela)

Stephanie Jo De Neff and David M. Sever
Department of Biology
Saint Mary's College, Notre Dame, Indiana 46556

Abstract

Phototactic behavior was studied for five different developmental stages of the tiger salamander, *Ambystoma t. tigrinum* (Green). Specimens from a vernal pond in Indiana were given the choice between a light or dark chamber. Chi squares were significant ($P < .01-.005$) for positive phototaxis for three stages of the aquatic larvae. The two terrestrial stages of specimens collected immediately after metamorphosis and adults were significantly photonegative ($P < .005$). The difference in phototactic behavior between aquatic and terrestrial stages is probably related to environmental factors influencing development and survival of *A. t. tigrinum* in these habitats. The photopositive orientation of the larvae may be an adaptation for increasing developmental rate by orienting the larvae to the warmest parts of the pond. The photonegative newly metamorphosed individuals and adults are fossorial and nocturnal.

Introduction

Phototactic orientation has been noted in various species of *Ambystoma*. Photopositive orientation was observed in the larvae of *A. maculatum* (15) and in the larvae (6) and adults (11) of *A. ordinarium*. Negative phototaxis was observed in the older larvae of *A. opacum* (9) and in the young larvae and adults of *A. macrodactylum croceum* (1, 3).

Reversal of phototaxis has been found during ontogeny of two species of *Ambystoma*. Anderson (3) found *A. macrodactylum sigillatum* to be photopositive in the larval stage reversing to negative phototaxis at metamorphosis. Marangio (11) found *A. opacum* to be photopositive in early larval stages reversing to photonegative orientation with the development of hindlimbs.

The phototactic behavior of *A. tigrinum* (Green), the widest ranging species in the genus, has never been studied. There are seven subspecies in North America, and the subspecies in Indiana, *A. t. tigrinum,* occurs throughout most of the eastern United States exclusive of the Appalachian highlands (10). Many authors have noted that adult *A. t. tigrinum* are nocturnal and fossorial (7, 12, 13, 16), and field studies by Dineen (8) and Anderson and Graham (5) indicate that the larvae are active at night. It was the purpose of this study to conduct laboratory tests on the phototactic behavior of larval, newly metamorphosed and adult individuals of *A. t. tigrinum* from a temporary pond in Indiana.

Materials and Methods

Eggs, larvae, newly metamorphosed individuals and adults of *A. t. tigrinum* were collected in 1976 from a vernal pond in St. Joseph County, Indiana. Eggs were kept at 12 C until Harrison stages 44-45 (14). The temperature was then raised to 16 C and larvae hatched within four days. These newly hatched larvae and all other salamanders collected were kept in aquaria in an incubator with a constant temperature approximating the temperature of the pond at the time of collection.

Chambers used for testing all salamanders except newly hatched larvae were modified from three 26 X 50 X 30 cm aquaria. Two of the aquaria were control chambers, and the remaining aquarium was the test chamber. In the center of each aquarium was a 15 X 18 cm open ended can with a 5 X 8 cm opening cut into the base on either side. Glass dividers, 6 X 17 cm, extended from the can to the sides of the aquarium. These pieces were secured with aquarium sealer, and the entire apparatus was painted opaque black.

The aquaria were supplied with pond water and placed beneath two 40 W fluorescent lights with approximately 125 FC of light reaching the water surface. One side of the test chamber was covered with a heavy cardboard lid for the dark condition while the other side was left exposed to the light source. One of the control chambers was covered entirely and the other left completely exposed.

The newly hatched larvae were tested in three smaller aquaria, 27 X 19 X 10 cm. Each aquarium was divided in half by a 19 X 10 cm piece of glass raised 1.5 cm from the bottom to allow a space beneath the divider for placing the specimen to be tested. These aquaria were painted and set up in the same manner as the larger chambers.

Specimens tested were classed according to their developmental stage. Adults (83-114 mm snout-vent length) were collected and tested during the breeding season in early March. Newly hatched larvae (14-17 mm SVL) were tested within one week after hatching in mid-April. Intermediate larvae (18-38 mm SVL), characterized by developed forelimbs, were collected and tested in mid-May. Large larvae (36-62 mm SVL), *i.e.*, those possessing developed hindlimbs, were collected and tested in early July. In mid-July the pond began drying and larvae were metamorphosing and emigrating from the pond. Newly metamorphosed specimens (55-64 mm SVL) were collected from pit traps as they left the pond.

Adults, newly hatched and intermediate larvae were tested between 1700-2200 hours. Large larvae and newly metamorphosed individuals were tested between 700-1200 hours. For each trial, the aquaria were supplied with a depth of 3.5 cm of fresh pond water. One animal was placed in each chamber at a time, either within the can or, for the newly hatched larvae, beneath the glass divider. After 18 minutes, the position of the salamander was recorded as either being in the dark or light side of the chamber. The few animals that remained within the can or beneath the divider were disregarded in the computations. At least 20 individuals were tested in all experimental and control situations for each developmental stage. Results were subjected to chi square analysis.

Results

Chi squares were significant for positive phototaxis for the three larval stages and negative phototaxis for newly metamorphosed and adult *A. t. tigrinum* (Table 1). The values of chi-square computed were highly significant when compared with critical values in standard chi-square tables. $P < 0.005$ for all tests except for large larvae in which $P < 0.01$. The controls at all stages were randomly distributed between the two sides ($P < 0.05$-0.001) indicating that the orientation found was not due to factors other than the light variable being tested. Two of the newly hatched larvae and two of the large larvae in experimental chambers did not move to either side and were disregarded in the analyses.

TABLE 1. *Results of light-dark choice tests for* Ambystoma t. tigrinum. X^2 *is the computed chi-square value.* $P < 0.005$ *in all tests except for large larvae in which* $P < 0.01$.

Developmental stage	N	Light	Dark	X^2
Newly hatched larvae	48	36	12	12.0
Intermediate larvae	20	17	3	9.8
Large larvae	28	21	7	7.0
Newly metamorphosed	30	4	26	16.1
Adults	20	1	19	16.2

Discussion

During the year of this study, eggs were laid throughout March and hatched in April. The pond dried completely by the end of July, and a considerable number of large larvae desiccated before completing metamorphosis. In this pond, selection favors larvae possessing adaptations enabling them to develop fast enough to metamorphose during the short period of the pond's existence.

Anderson (2) found that photopositive behavior in larval *A. macrodactylum sigillatum* oriented them to the warmest parts of ponds. *A. t. tigrinum* larvae collected in the daytime for the present study were associated with the warmer, shallower areas of the pond. Anderson (4) found that an increase in ambient water temperature increases developmental rate of *Ambystoma* larvae which experience short growing seasons. Thus, the photopositive orientation we found in *A. t. tigrinum* larvae may be an adaptation for increasing developmental rate by orienting the larvae to the warmest parts of the pond.

Various reports (7, 12, 13, 16) indicate that the terrestrial stages of *A. t. tigrinum* are nocturnal and fossorial. This is consistent with the results that adult and newly metamorphosed individuals in this study were photonegative.

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Effects of Prolactin on Active Sodium Transport Through the Skin of Hypophysectomized Newts[1]

T. H. GIESKE, Department of Biology
Indiana University at South Bend

Abstract

Plasma osmolalities and sodium fluxes across isolated, short circuited sections of abdominal skins were measured in sham-operated and totally hypophysectomized newts *(Notophthalmus viridescens)*. These newts were injected intraperitoneally, each day for 7 days, with an isotonic saline solution either without (control) or with dissolved hormones. The hormone treated groups received one of the following injections: either 25 ug prolactin with 25 ng thyroxine, 25 ug prolactin, 25 ng thyroxine, 25 ug aldosterone, or 115 ng arginine vasotocin. The volume of the injection was 0.05 ml. On the seventh day hypophysectomized newts had significantly lower plasma osmolalities compared to intact and sham-operated newts. Hypophysectomized newts had a significantly higher Na+ efflux (passive) across the skin with a normal Na+ influx (active). The increased Na+ efflux and the decreased plasma osmolality were prevented by exogenous prolactin, particularly when combined with thyroxine. In contrast, neither thyroxine alone, aldosterone, nor arginine vasotocin prevented the increased Na+ efflux or the decreased plasma osmolality following hypophysectomy. In sham-operated newts both aldosterone and arginine vasotocin increased the active Na+ influx without altering the Na+ efflux across the skin. However, neither aldosterone nor arginine vasotocin increased the Na+ influx in hypophysectomized newts, suggesting a dependency on other pituitary factors. Prolactin influences the permeability to Na+ at the cutaneous surface; thus it may have an osmoregulatory function in this species of salamander.

Introduction

Removal of the entire pituitary gland interferes with the ability of adult, aquatic newts (*Notophthalmus viridescens*) to survive in water (4, 7). Connelly, Tassava and Thornton (4) demonstrated that prolactin, particularly in combination with thyroxine, prolongs survival of the adult hypophysectomized newts, although thyroxine alone was ineffective. One of their hypotheses was that prolactin might have an osmoregulatory capacity in the newt. The eft water drive, which is stimulated by prolactin, also suggests a possible osmoregulatory influence for prolactin (11). Possible prolactin interactions in sodium and water balance have been studied in several amphibians: in *Triturus cristatus* (15, 19), in *Rana pipiens* and *Taricha torosa* (5), in *Notophthalmus viridescens* (3), in *Xenopus laevis* (21), in *Ambystoma mexicanum* (23, 24), in *Necturus maculosus* (18), and in *Bufo marinus* (6). Conflicting results have been reported and no general relationship between prolactin and osmoregulation in amphibians as a group can be made yet. In most of these studies the researchers elucidated the effects of hypophysectomy and either hormone replacement (started several days after hypophysectomy) or hormone maintenance therapy (started immediately after hypophysectomy) on plasma sodium concentrations. Only in a few studies did the investigators study changes in sodium or water exchange at any of the major sites of exchange. This paper reports the effects of hypophysectomy and hormonal maintenance therapy on sodium fluxes

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through the skin of the adult eastern, spotted newt (*Notophthalmus viridescens*) and on the plasma osmolality.

Materials and Methods

Aquatic, adult newts (*Notophthalmus viridescens*) were obtained from Mogul-Ed, Oshkosh, Wisconsin. They were kept in an aerated, filtered solution containing: 3.8 mM Na^+, 2.9 mM Cl^-, 0.8 mM Ca^{++}, 0.1 mM K^+, and 0.2 mM HCO_3^- at 21-23°C with a pH between 7.0-7.2. Lighting conditions were not controlled. Sham-operated and totally hypophysectomized newts were randomly distributed into seven groups: (1) uninjected; or those which received daily injections for a week of either (2) 0.7% NaCl, (3) 25 μg prolactin, (4) 25 ng thyroxine, (5) 25 μg prolactin with 25 ng thyroxine, (6) 25 μg aldosterone, or (7) 115 ng arginine vasotocin. All hormones were dissolved in isotonic saline in such a concentration that an injection of 0.05 ml of solution delivered the desired amount. All injections were given intraperitoneally to unanesthetized newts through a 30 gauge hypodermic needle passed under the caudal skin into the posterior peritoneal cavity. Aldosterone was purchased from Calbiochem, Los Angeles, California; synthetic arginine vasotocin from Sandoz Pharmaceuticals, Hanover, New Jersey; and thyroxine from Baxter Laboratories, Morton Grove, Illinois. The prolactin (NIH-P-B8) was provided by the NIH Endocrine Study Section, Bethesda, Maryland.

Hypophysectomy was performed by the method of Schotte and Hall (20). Surgical anesthesia was obtained by immersing the newts in 0.3% (w/v) tricaine- methane sulfonate (Kent Chemical Company, Vancouver, British Columbia). After removing a flap of the sphenoid bone directly ventral to the pituitary gland, the entire pituitary was removed by suction through a small glass pipette. Afterwards, the bone flap was replaced. The sham-operated newts were treated similarly except the pituitary gland was not removed. Totally hypophysectomized newts do not molt; in 2-3 days they develop a rough, black skin which is easily distinguished from the smooth, dark green skin of the intact newt (7). This feature can be used as an index of total hypophysectomy (7). Therefore, any hypophysectomized newts, except those treated with thyroxine, which showed signs of molting or failed to develop the characteristic rough, black skin were discarded. Hypophysectomized newts treated with thyroxine retained the normal skin coloration and smoothness; in these newts the adequacy of hypophysectomy was determined by postmortem examination of the brain histologically.

After the newts were treated for 7 days as described above, they were decapitated and a ventricular blood sample was taken. Then the abdominal skin was removed for *in vitro* permeability studies by the short-circuited procedure developed by Ussing and Zerahn (22). With the aid of a dissecting microscope, the musculature was peeled from the inner surface of the skin with care being taken to avoid tearing the skin. The skin was placed in an interlocking ring system which was held between the halves of a lucite bathing chamber containing 4 ml of a buffered amphibian Ringer's solution on each side of the skin. The pH of the solution was 7.4 ± 0.1, the temperature was 22 ± 2°C and the osmolality was 241-246 mOsm/Kg H_2O. The area of the bathed skin was 2.3 cm^2. After a 30 min equilabration period, 100 μl of a radioactive solution containing 1.0 μCi of ^{22}NaCl was added to one side of the chamber. At 1 and at 10 min a 20 μl sample was taken from that same side to check both the completeness and rapidity of mixing of the radioisotope and to check for any leaks in the system (e.g., small holes in the bathed skin). Thereafter, a 20 μl sample was taken from the opposite side (initially unlabelled chamber) for 3 hrs. The osmolality of the plasma was determined by the micromelting point technique of Drucker and Schreiner (8). Analyses of the significance of differences among the treatment and control groups were made using the t-test developed by Dunnett (9).

Results

On the seventh day the saline injected hypophysectomized newts had a lower plasma osmolality than the corresponding group of sham-operated newts (Table 1). This drop in plasma osmolality was prevented by the maintenance therapy with prolactin and thyroxine in combination. Prolactin treatment alone was less effective at the dose used. Thyroxine alone, as well as aldosterone and arginine vasotocine alone, was ineffective. In sham-operated newts the plasma osmolality was not significantly altered by any of the treatments (Table 1).

The effects of hypophysectomy and the various hormonal maintenance therapies on the cutaneous fluxes of sodium, measured under short-circuited conditions *in vitro*, are shown in Table 2. Under short-circuited

TABLE 1. *The effects of hormone treatments on the plasma osmolality of sham-operated and totally hypophysectomized newts. The osmolalities were measured on the seventh day of treatment.*

Group	Treatment	Injection	Dose/newt	Plasma Osmolality mOsm/Kg HOH
(1)	Sham-operated (SO)	None	-----	-------
(2)	SO	Saline	0.05ml 0.7%	242±15
(3)	SO	Prolactin & Thyroxine	25ug+25ng	243±16
(4)	SO	Prolactin	25ug	244±16
(5)	SO	Thyroxine	25ng	242±12
(6)	SO	Aldosterone	25ug	241±14
(7)	SO	Arginine Vasotocin	115ng	238±15
(1)	Hypophysectomized (Hy)	None	-----	-------
(2)	Hy	Saline	0.05ml 0.7%	181±14*
(3)	Hy	Prolactin & Thyroxine	24ug+25ng	231± 6
(4)	Hy	Prolactin	25ug	206±17*
(5)	Hy	Thyroxine	25ng	182±20*
(6)	Hy	Aldosterone	25ug	191±19*
(7)	Hy	Arginine Vasotocin	115ng	180±10*

N=6 newts/group.

Mean ± standard deviation.

* significantly different from sham-operated—saline injected group at = 0.01.

TABLE 2. *The effects of hormone treatments on sodium fluxes across isolated, short-circuited skins of sham-operated and totally hypophysectomized newts. On the seventh day of treatment the fluxes of Na+ were measured* in vitro *under short-circuited conditions using* ^{22}*Na.*

				Na+ Fluxes uEq/cm^2/hr		
Group	Treatment	Injection	Dose/newt	Influx	Efflux	Net Flux
(1)	Sham-operated (SO)	None	-----	0.56±0.13	0.15±0.07	0.42±0.15
(2)	SO	Saline	0.05ml 0.7%	0.60±0.10	0.16±0.04	0.43±0.06
(3)	SO	Prolactin & Thyroxine	25ug+25ng	0.52±0.11	0.14±0.06	0.38±0.10
(4)	SO	Prolactin	25ug	0.52±0.19	0.17±0.04	0.35±0.19
(5)	SO	Thyroxine	25ng	0.53±0.18	0.16±0.08	0.36±0.18
(6)	SO	Aldosterone	25ug	0.99±0.16*	0.15±0.06	0.84±0.22*
(7)	SO	Arginine Vasotocin	115ng	0.85±0.13*	0.14±0.07	0.71±0.12*
(1)	Hypophysectomized (Hy)	None	-----	0.62±0.11	0.47±0.07*	0.15±0.07*
(2)	Hy	Saline	0.05ml 0.7%	0.63±0.13	0.50±0.09*	0.13±0.10*
(3)	Hy	Prolactin & Thyroxine	25ug+25ng	0.58±0.07	0.20±0.06	0.38±0.12
(4)	Hy	Prolactin	25ug	0.55±0.07	0.26±0.06	0.30±0.08*
(5)	Hy	Thyroxine	25ng	0.64±0.10	0.42±0.09*	0.22±0.06*
(6)	Hy	Aldosterone	25ug	0.64±0.06	0.41±0.06*	0.23±0.05*
(7)	Hy	Arginine Vasotocin	115ng	0.64±0.09	0.47±0.11*	0.17±0.05*

N = 10 newts per group.
Mean ± standard deviation.
* significantly different from sham-operated—saline injected group at $\alpha = 0.01$.

conditions *in vitro,* sodium is actively transported inward across the skin of the newt and passively diffused outward across the skin; the net flux of sodium equals the measured short-circuit current across the skin (10). Although hypophysectomy did not alter the active Na+ influx, there was an increased passive Na+ efflux following hypophysectomy. This increased Na+ efflux in the hypophysectomized newt skin was prevented either by prolactin alone or by prolactin in combination with thyroxine. In contrast, treatment with thyroxine alone, aldosterone or arginine vasotocin did not reduce or prevent this increased Na+ efflux. In the sham-operated newts aldosterone and arginine vasotocine increased the active Na+ influx without altering the passive Na+ efflux. But this effect was not observed in the hypophysectomized newts on the seventh day. Exogenous prolactin, either alone or in combination with thyroxine, did not decrease Na+ efflux in the sham-operated newts, as was seen in the hypophysectomized newts.

Discussion

Following hypophysectomy the plasma osmolality decreased significantly. Maintenance treatments with prolactin alone partially prevented this decrease, but a combined treatment with prolactin and thyroxine was more effective. This relates to the finding of Connelly *et al.* (4) that a prolactin-thyroxine treatment promoted survival of the aquatic adults better than a prolactin treatment alone. Death following hypophysectomy is probably due to an inability to regulate water and electrolyte balance. Brown and Brown (3) reported that following hypophysectomy in *Notophthalmus viridescens* plasma Na+ concentrations decreased. They reported, however, that either prolactin alone or corticosterone alone partially reverses the decreased plasma Na+ concentrations. However, there was no apparent synergism between prolactin and corticosterone when administered together. In other amphibians plasma Na+ concentrations also fall after hypophysectomy or adenohypophysectomy (5, 16, 18, 19, 23, 24). But differences in the effectiveness of hormones have been reported. In *Necturus maculosus* a prolactin treatment started on the sixteenth day after hypophysectomy only partially corrected the fall in plasma Na+; whereas, a prolactin treatment started on the same day of hypophysectomy completely prevented the hyponatremia by somehow decreasing the Na+ efflux across one or more of the membranes of exchange with the external environment (18). In *Triturus cristatus* either prolactin or aldosterone corrected the hyponatremia following hypophysectomy (19). Adenohypophysectomy of *Bufo marinus* causes a progressive hyponatremia, which can be corrected with glucocorticoids (cortisol or corticosterone) but not with aldosterone (16). In adenohypophysectomized *Rana pipiens* prolactin did not correct the hyponatremia (5). In adenohypophysectomized *Taricha torosa* neither prolactin alone nor aldosterone alone restored plasma Na+ levels to normal, but when given together they partially corrected plasma Na+ concentrations (5). In hypophysectomized, larval *Ambystoma mexicanum* prolactin is an effective hormone (23, 24). It is hard to explain these apparent inconsistencies at this time; but, differences in dosages, treatment schedules, and physiological aspects (e.g., aquatic dependency of the species) may be involved.

The hyponatremia following hypophysectomy may not be due entirely to a loss of Na+ to the environment. Water balance and water turnover rate could be involved. In adenohypophysectomized *Rana pipiens* cutaneous permeability to water is increased (12, 13). This could lead to a diluting effect on plasma components. In premetamorphic larvae of *Xenopus laevis* the turnover rate of water is depressed by hypophysectomy and is restored to normal by prolactin (21). Redistribution of Na+ within the various compartments of the body is also a possibility.

There are fewer studies on the possible sites of action of prolactin. Wittouck (24) reported that the isolated gills from hypophysectomized, larval *Ambystoma mexicanum* absorbed less Na+ from a NaCl solution than the isolated gills from intact animals; prolactin enhanced absorption of Na+ in both groups. Adenohypophysectomy of *Rana pipiens* increases the passive efflux of Na+ and decreases the active transport of Na+ (influx) across the skin; these changes are partially prevented by ACTH or aldosterone (17). In adenohypophysectomized *Bufo marinus* urine flow, urine osmolality, and urine Na+ concentration were not significantly different from the sham-operated, intact toads (16). Dalton & Snart (6) reported a stimulatory action of exogenous prolactin on the active transport of Na+ by the isolated, short-circuited bladder of

Bufo marinus; but, a similar effect was not shown in the isolated short-circuited skin of *Bufo marinus* or *Rana pipiens*. Prolactin stimulated the active transport of Na^+ by increasing the passive permeability to Na^+ at the mucosal surface of the urinary bladder (this allows more Na^+ to diffuse inward to the site of the transport carrier molecules) (6). In the present study prolactin, particularly in combination with thyroxine, decreased the passive permeability to Na^+ (efflux) in the skin of hypophysectomized newts. Active Na^+ influx was not altered by hypophysectomy or by prolactin. This would aid in a positive Na^+ balance. The mechanism of action is not known, but perhaps prolactin influences the passive permeability to Na^+ by stimulating the production of mucus (26). In the adult newt the kidneys and urinary bladder are other possible sites of action for prolactin. Prolactin did not reduce the passive cutaneous permeability to Na^+ in the intact newts, although it had this effect in the hypophysectomized newts. Possibly the endogenous secretion of prolactin was near maximal levels, thus the exogenous prolactin would not have produced a significant change in permeability to be detected. A similar lack of a detectable response to prolactin in intact axolotls has been observed (25). If prolactin stimulates mucus secretion, then it might also be possible that the exogenous prolactin might not have been sufficient to increase significantly the mucus layer on the skin and thus detectably alter the permeability to Na^+.

Although aldosterone and arginine vasotocin were not effective in correcting the hyponatremia in hypophysectomized newts, they did stimulate independently the active transport of Na^+ in the sham-operated, intact newts, but not in the hypophysectomized newts. Because they were effective in the intact newts, tachyphylaxis can be ruled out as an explanation for the lack of response in the hypophysectomized newts. Some pituitary factor or pituitary dependent factor is necessary before either aldosterone or arginine vasotocin can stimulate the cutaneous active transport of Na^+ in the newt. In a separate study (unpublished) arginine vasotocin effectively stimulated active Na^+ transport in the newt skin 4 hrs after hypophysectomy (when it is likely that the necessary factor was still present or the target tissue was still affected by the factor previously secreted) but not after 4 days (when the necessary factor would probably have been metabolized). Refractoriness to posterior pituitary hormones, which normally increase the cutaneous permeability to water in anurans, has been reported in adenohypophysectomized frogs by Jones and Steggarda (12) and by Levinsky and Sawyer (13). The refractoriness to exogenous antidiuretic hormone could be prevented by administering both ACTH and thyroxine together (13). Stimulatory effects of aldosterone and ADH on Na^+ transport have been reported in anurans and urodeles (1, 2, 14).

Prolactin is involved in the electrolyte balance of the newt, *Notophthalmus viridescens*, because it influences the cutaneous permeability to Na^+. Whether this is a direct action or an indirect action is still unknown. Similar studies should be done in the larval and eft stages of this newt. Perhaps this could give a better insight into the migration to a semiterrestrial habitat after metamorphosis and the subsequent migration back to water (second "metamorphosis") that is characteristic of this and related newts.

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Pineal Gland Prothyroid Stimulating Substance in White Leghorn Cockerels

WALTER R. RATHKAMP, Saginaw Valley State College
University Center, Michigan 48710

Abstract

Pinealectomy in 2 day old White Leghorn cockerels resulted at 50 days of age in a significant decrease in thyroid weight, which was independent of body weight. The effect was first noted at 40 days but disappeared by 70 days. Analysis of anterior pituitary glands from experimental animals showed that at 50 days of age there was a significant increase in thyroid stimulating hormone (TSH) content of pinealectomized animals as compared to sham and control animals. By 70 and 80 days of age a significant decrease in anterior pituitary TSH content of pinealectomized animals was noted. Propylthiouracil fed birds showed a significant increase in pineal weight as compared to control fed animals. Subsequent treatment with thyroxine reversed the effect of propylthiouracil treatment returning pineal weights back to control levels.

Results indicate that there is a prothyroid stimulating substance produced by the pineal gland between 40 and 60 days that causes an increase in thyroid weight. This effect, however, is only transitory in nature as shown by the return of thyroid weight to normal without additional treatment to pinealectomized birds. The pineal gland was also shown to be sensitive to the levels of thyroxine produced by the thyroid, indicating a possible feedback relationship between the thyroid and pineal gland.

Introduction

Through the years, a number of endocrine functions have been attributed to the pineal gland; investigations of the avian pineal gland have been contradictory at best. Recently it has been shown by numerous investigators that environmental lighting plays a major role in pineal function (1, 2, 5, 6, 7, 11, 12, 18, 17, 18, 19). These studies have shown the extreme sensitivity of the pineal gland to varying environmental lighting which may be held responsible for some of the early contradictory results obtained when working with the pineal gland.

The mammalian pineal gland has been intensely investigated as to its role in reproduction and its effects on other endocrine glands. It has recently been shown (3, 8, 10) to be a thyroid inhibitor, which may be due to the release of melatonin in the rat, but opinions differ as to how this effect is mediated. The gonadal and extra gonadal effects of the avian pineal gland have not been as extensively investigated as the mammalian pineal gland and most investigations have not taken into consideration environmental lighting (13, 14).

This investigation was undertaken to determine the effects of pinealectomy on immature White Leghorn cockerels, with special care taken to control the lighting conditions to which animals were exposed.

Materials and Methods

Animals. The single comb White Leghorn cockerels used in these experiments were obtained when 1 day old from the State Farm Bureau Co-op., Indianapolis, Indiana. All birds not autopsied within the first 48 hours were maintained in cages in controlled temperature (72°F) and light (14L:10D) rooms and supplied with food and water *ad libitum.*

Pinealectomy. Chicks when 2 days old were anesthetized with ether and a small piece of skin at the apex of the head was removed. A median V-shaped incision was made through the skull at the fusion of the frontal and parietal bones. The pineal gland was then removed with a pair of fine pointed forceps placed under the incision. The skull flap was then replaced, and a wound clip was applied to the skin. Sham operations were performed in the same manner with the exception that the pineal gland was not removed. At autopsy birds showing residual pineal tissue were discarded.

Three groups of animals (intact controls, sham operated, and pinealectomized) were maintained for 40, 50, 60, 70, and 80 days. Special care (cage rotation) was taken to maintain equal numbers of each group at specific cage levels, to avoid differences in lighting to each group of birds. At autopsy, body, comb, testes, adrenal, thyroid, pineal, and pituitary weights were taken. The comb factor (length in mm × height in mm/2) was also determined at this time. The anterior pituitaries were placed in acetone and refrigerated for later use in assays of pituitary TSH content.

TSH Assay. (4) The animals used in these assays were 2-day-old cockerels maintained without food or water. The animals were divided randomly into groups of ten birds for later treatment. Group 1 acted as control in each experiment receiving water injections. Groups 2, 3, and 4 received varying dosages of Bovine B-5 NIH-TSH (0.003U, 0.006U, and 0.012U/bird). The remainder of the treated groups received 1.5 mg. equivalent fresh anterior pituitary gland obtained from pooled pituitaries of intact, sham, or pinealectomized birds. Injections were made subcutaneously in the neck region, 0.2cc/bird, five hours before autopsy.

In addition each bird received 3.0 uc ^{32}P in 0.2cc distilled water one hour before autopsy. At autopsy chicks were sacrificed by cervical dislocation and the thyroids were removed, cleaned, weighed, and placed on individual planchets. The thyroids were then dried under a heat lamp for one hour and their radioactivity counted on a Nuclear Chicago automatic gas-flow counter. Results were expressed as counts per minute minus background per milligram of wet tissue (cpm-BG/mg). The TSH was a gift from the NIH Endocrinology Study Section.

Thyroid-Pineal Feedback. In an effort to clarify the possible pineal-thyroid relationship an experiment was performed to determine if there was a feedback relationship between these two glands. Animals used in this experiment were 50 days of age at sacrifice. The animals were divided into 5 groups at random, one group acting as controls received normal feed while groups 2-5 received 0.1% propylthiouracil (PTU), by weight, in the feed for 7 days. Groups 1 and 2 were injected for 4 days before sacrifice with 0.2 cc distilled water per bird subcutaneously in the neck region, while groups 3-5 received varying dosages of thyroxine (T_4), (5 ug to 20 ug/day). Animals were sacrified by cervical dislocation, and the pineals, thyroids, and anterior pituitary glands were removed and weighed. L-Thyroxine was purchased from Calbiochemical, La Jolla, California.

Statistical Analysis. In all statistical comparisons, analysis of var-

TABLE 1. *The Effects of Pinealectomy at 2 days of age on 40, 50, 60, 70, and 80 Day Old Cockerel Organ Weights.*

	N	Body g±SE	Comb g±SE	Comb Factor	Testes mg±SE	Pituitary mg±SE	Thyroid mg±SE	Thyroid % Body Weight
40 day C	8	323.0± 6.0	1.7±0.3	428.0± 22.0	74.8± 5.6	4.5±0.3	17.1±0.6	0.0053
40 day S	8	319.0± 8.0	1.9±0.2	471.0± 34.0	76.0± 5.4	4.1±0.5	15.0±1.2	0.0047
40 day P	8	284.0±12.0**	1.0±0.1	318.0± 25.0*	64.4± 5.3	4.0±0.2	13.1±0.5**	0.0047
50 day C	8	410.0± 6.0	1.7±0.2	579.0±151.0	121.9± 7.3	5.0±0.1	21.6±0.8	0.0053
50 day S	8	443.0±11.0	1.9±0.3	602.0±187.0	120.1±11.5	5.1±0.3	27.4±6.1	0.0051
50 day P	8	338.0±12.0**	1.1±0.2*	352.0±101.0*	89.5± 6.1*	4.7±0.5	13.8±0.6**	0.0041*
60 day C	10	542.0±11.0	3.0±0.3	657.0± 67.0	133.6± 8.5	5.7±0.3	26.1±1.6	0.0050
60 day S	9	490.0± 7.0	4.1±0.4	949.0± 87.0	168.6±13.5	5.7±0.2	26.9±1.1	0.0055
60 day P	7	404.0±28.0**	1.9±0.2*	468.0± 48.0**	96.1± 9.1*	5.3±0.9	22.8±2.0	0.0057
70 day C	13	605.0±18.0	4.5±1.3	1069.0± 68.0	181.3±14.0	5.9±0.3	28.1±1.0	0.0047
70 day S	8	565.0±25.0	4.2±0.8	1000.0±148.0	211.6±11.7	5.8±1.0	27.4±2.1	0.0048
70 day P	6	542.0±11.0	4.1±0.8	927.0± 39.0	190.3±51.5	6.0±0.4	24.0±2.5	0.0045
80 day C	9	784.0±42.0	6.9±1.5	1294.0±157.0	278.3±28.0	6.2±1.2	44.0±6.1	0.0057
80 day S	8	812.0±35.0	9.1±1.4	1698.0±161.0	369.8±54.4	6.9±0.2	39.6±2.8	0.0049
80 day P	7	765.0±38.0	7.6±1.7	1492.0±194.0	367.0±53.6	6.4±0.2	52.2±4.2*	0.0069*

* significant at 5% level.
** significant at 1% level.
C = Control.
S = Sham.
P = Pinealectomized.

iance was employed. First comparing for any signification variation between the groups then by partitioning and comparing with control animals.

Results

The results of pinealectomy are shown in Table 1. At 40 days of age pinealectomized cockerels showed a significant decrease in body, comb, and thyroid weight, as well as a decrease in comb factor. These weights continued to be significantly lower in 50- and 60-day-old cockerels with an additional significant decrease in testes weight of pinealectomized birds. By 70 days of age the body weights of pinealectomized birds returned within normal range of control and sham weights. On the basis of percent body weight, the thyroid weight of 50-day-old pinealectomized birds was still significantly decreased. In an additional study of 50-, 70-, and 80-day-old birds the results parallel those already described and only the data for 80-day-old birds is noted where a significant increase in thyroid weight was observed. There was no change detected in adrenal or pituitary weights.

In a further effort to verify the results obtained following pinealectomy, anterior pituitary TSH content for the different groups was also determined (Table 2) to see if there was a correlation between observed decreases in thyroid weight and pituitary TSH content. Anterior pituitaries from 50-day-old pinealectomized animals showed a significant increase in TSH content while 40- and 60-day-old animals were shown to have the same amounts of TSH present in their pituitaries. At 70 and 80 days of age there was a reversal in TSH content found in which anterior pituitaries from pinealectomized birds showed a significant decrease in TSH content.

Propylthiouracil (PTU) and thyroxine (T_4) treatment (Table 3) showed that birds that received PTU treated feed had a significantly increased pineal weight, as well as, pituitary and thyroid weights at 50 days of age, when compared to control fed animals. Subsequent treatment with 10 and 20 ug. of thyroxine resulted in weights that showed no statistical difference when compared to control animals.

TABLE 2. *Assay of Anterior Pituitary TSH from 40, 50, 60, 70, and 80 Day Old Intact Sham Operated and Pinealectomized Cockerels. Each group contained 10 assay birds.*

	Thyroids cpm—BG/mg±SE				
Treatment	40 Day	50 Day	60 Day	70 day	80 Day
Water Controls	45.6± 2.7	30.1±2.9	31.0±2.2	40.9±2.9	44.9±1.7
0.003U NIH TSH	84.9± 7.4	64.7±3.4	72.5±2.5	77.1±2.6	88.5±3.4
0.006U NIH TSH	134.1±10.5	93.5±4.2	92.0±4.3	106.5±5.5	124.4±6.5
0.012U NIH TSH	184.8± 6.7	112.1±6.2	120.8±3.5	147.0±7.1	147.7±7.2
1.5mg AP from intact donors	111.1±10.5	43.1±2.5	69.0±3.1	71.8±4.8	73.9±3.5
1.5mg AP from sham donors	111.0± 6.7	42.4±2.4			
1.5mg AP from pineal-			66.5±5.3	70.3±2.2	71.7±2.5
ectomized donors	130.0± 7.4	52.6±2.4**	65.4±2.9	60.5±3.4*	56.5±2.8**

* significant at 5% level.

** significant at 1% level.

TABLE 3. *The Effects of Propylthiouracil (PTU) and Thyroxine (T_4) Treatment on Pineal, Pituitary, and Thyroid Weights of 50 Day Old Cockerels*

Treatment	N	Thyroid mg±SE	Pituitary mg±SE	Pineal mg±SE
Control	10	27.0±1.5	5.3±0.1	3.5±0.1
PTU	10	48.7±3.7**	6.5±0.2**	4.1±0.1**
PTU+T_4 (5ug)	10	42.1±2.0**	6.2±0.2**	4.1±0.2**
PTU+T_4 (10ug)	10	32.5±2.0	5.7±0.1	3.7±0.1
PTU+T_4(20ug)	10	23.0±1.8	5.3±0.2	3.4±0.1

** significant at 1% level.

Discussion

Pinealectomy resulted in a significant decrease in thyroid weight in 50-day-old cockerels indicating a prothyroid stimulating substance. This effect was no longer observed at 70 days of age, indicating that the animals are capable of overcoming the absence of this pineal substance. This result is in contradiction to those found when working with rodents, in which it has been found the pineal is antithyrotropic (3, 8, 10). This difference could be accounted for by differences in species, as there is other evidence to indicate that avian and mammalian pineal glands differ in response to the same experimental conditions. An example of this is the response of the pineal gland to continuous light, the avian pineal shows increased hydroxyindole - 0 - methyl transferase (HIOMT) activity while under the same conditions the rat's pineal shows the opposite effect (2). A recent study by Oishi (9) showed that photoperiod changes could effect thyroid weights in Japanese quail and the observed effect could be reversed by pinealectomy, indicating a pineal-thyroid relationship in avian species. It was also noted that the effect decreased with increasing age.

Of even greater significance is a report by White, *et al.* (16), that showed the presence of significant amounts of gonadotropin-releasing hormone (Gn-RH) and thyrotropin-releasing hormone (TRH) in ovine, bovine, and porcine pineal glands. This presents the possibility that the prothyroid stimulating substance proposed by this investigation might in fact be TRH from the avian pineal gland.

That there is a prothyroid stimulating substance being released from the pineal gland of the White Leghorn cockerel was further supported by results of TSH analysis of the anterior pituitaries from experimental birds. Ablation of the pineal gland would remove the prothyroid stimulating substance from the animal which could prevent or at least not stimulate the release of TSH from the anterior pituitary. If this were the case, elevated levels of TSH would be expected in 50-day-old pinealectomized animals and decreased levels in 70- and 80-day-old animals. The data from the experiments presented here support this hypothesis.

If the relationship between the pineal and thyroid gland is hormonal, a feedback mechanism should be expected. The data presented here supports this mechanism as shown by the sensitivity of the pineal gland to the levels of thyroxine while the thyroid gland in turn is influenced by a pineal substance.

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The Influence on Hybridization Between *Drosophila melanogaster* Females and *D. simulans* Males of Early Exposure to the Other Species

MICHAEL EOFF, Department of Biology
Marian College, Indianapolis, Indiana 46222

Abstract

(1) Under the conditions of these experiments, early exposure of young (0-24) *Drosophila melanogaster* females to *simulans* males had no effect on interspecific isolation when the same females were three to four days old. (2) An insemination of a *melanogaster* female by a *simulans* male significantly reduces the probability of an insemination by a second *simulans* male. (3) To score small mass mating vials without determining exactly what percentage of the females is inseminated results in an overestimate of hybridization, since the insemination of just one female can cause a small mass mating vial to be scored as a mating. (4) Isolation between these two species varies widely from one experiment to the next, even under supposedly uniform conditions.

Introduction

Various factors influencing the isolation between *Drosophila melanogaster* and *D. simulans* have been studied. These include differences between strains (1, 13), mixed cultures (5, 8), being reared in isolation rather than in conspecific cultures (9), artificial selection (6, 7), and age (2, 3, 14). The purpose of the research reported here is to determine whether *melanogaster* females between three and four days of age hybridize more readily with *simulans* males if they have been in the company of *simulans* males for the three preceding days than if they are exposed to *simulans* males for the first time at three to four day of age.

Methods and Materials

I made stock bottles of yellow *melanogaster*, wild type *simulans*, and yellow *simulans*. Yellow is a sex-linked recessive gene, and the stock was made from a multiple sex-linked marker stock (y ct^6 ras f). The *simulans* stocks were lab stocks which had been maintained for years by mass-culturing.

Stock bottles of a particular type were always begun with eggs laid by the same number of flies during any particular experiment, in order to maintain population density relatively constant. However, more *simulans* were always used to lay eggs in *simulans* bottles in order to compensate for either lower fecundity (4, 17) or the greater loss of *simulans* pupae which are more often formed on the surface of the medium and suffocated if submerged (15).

All crosses were made in eight-dram food vials plugged with cotton and cultured at about 27° C. in a constant temperature incubator in which trays of water maintained high humidity. Constant light was provided by a 40-watt bulb located a few inches above the same shelf on which the vials were placed and between one and three feet from them. The food was made from tap water, methyl parasept, brewer's yeast, molasses, and cornmeal, and was always autoclaved a day or two before being used.

In the crosses described below, I judged whether mating had occurred by the presence or absence of unisexual broods of appropriate phenotype (5, 6, 7).

In order to determine the influence of early exposure to the other species, the following procedure was followed: female *melanogaster* collected on day 1 (and therefore between zero and twenty-four hours old) were divided into equal groups: one group (the counter-conditioning group) was placed, five per vial, in vials each of which contained five yellow *simulans* males (four to five days old), any offspring by which would be yellow; the other group (later to be used for control crosses) was placed, ten per vial, in vials for storage at room temperature with alternating periods of light and dark, until three to four days of age. In this way all vials, both for storage and mating, contained ten flies. Since mating behavior may be influenced by the number of stimuli received previously from other flies (10), it is important to equalize the numbers of flies in the two sets of vials.

At the end of the fourth day, the *melanogaster* females which were stored without *simulans* males were etherized and placed, five per vial, with five wild type *simulans* males (four to five days old) for four days. These were the control crosses. Also at the end of the fourth day, the *melanogaster* females which had been together with yellow *simulans* males on days two through four were removed from those vials (designated the counter-conditioning crosses), etherized, and mixed together before being redistributed, five per vial with five wild type *simulans* males (four to five days old) for four days. Any offspring by these males would be wild type. These constituted the experimental crosses.

At the end of four more days, all flies were etherized and, in the first experiment, discarded. In the second experiment, all surviving females were placed singly in food vials in order to determine exactly what percentage of flies had been inseminated in the controls. In the experimentals, because progeny by the two types of males would be different, placing females singly in food vials allowed for an exact determination of what percentage had been inseminated by the "first" (yellow) males, the "second" (wild type) males, and by both.

At this time I also recorded the number of dead flies of each sex, if any, since the alteration of the sex ratio during the experiment might alter the outcome. Statistical tests were later made to determine whether alteration of the number of sex ratio of flies in a vial influenced the mating results. Because preliminary crosses showed such different results from one experiment to the next, experimental and control crosses were always set up simultaneously.

All of the flies used in the above crosses were examined for macroscopic abnormalities (shrivelled wing, etc.) because of the importance of various body parts, especially the wings, in courtship, and only normal-appearing flies were used.

Results

The results of these two experiments are shown in Table I. Except when stated otherwise, all statistical tests mentioned were 2 x 2 con-

TABLE 1. *Number of crosses set up and number of five pair matings and individual females yielding progeny.*

Type of cross	No. of 5 pr. matings	Number yielding progeny	%	No. of females tested	No. of females inseminated	%
Experiment 1						
control	120	32	26.7	0	---	---
		3 (by 1st males)	2.4			
experimental	124	20 (by 2nd males)	16.1	0	---	---
		0 (by both)	0.0			
counter-conditioning	134	4	3.0	---	---	---
Experiment 2						
control	106	34	32.1	516	110	21.3
		21 (by 1st males)	19.8		24 (by 1st)	4.7
experimental	106	32 (by 2nd males)	30.2	512	98 (by 2nd)	19.1
		6 (by both)	5.7		1 (both)	.2
counter-conditioning	125	28	22.4	---	---	---

tingency tables with one degree of freedom, and Yates' correction factor was employed whenever the total sample was less than 40 or the expected number for any class was less than ten. Differences described as significant yielded probability values of less than 0.05.

In the first of these experiments only the results of the small mass matings are available, and there is a significant difference ($.05 > p > .01$) between the numbers of vials which yield progeny (of wild *simulans* males) in the experimental and control crosses (20 and 32, respectively). This indicates decreased hybridization after counter-conditioning. One should keep in mind, however, that the results of a small mass mating vial (having five females) may not reflect accurately the mating activities of individual females.

In the second experiment individual females were scored for inseminations. For both the five-pair matings and the female tests there is no significant difference between the numbers yielding progeny by wild type males in the control and experimental crosses (34 vs. 32 and 110 vs. 98, respectively). In the female tests, there is only one female which yielded progeny of both "first" and "second" males, compared to the nearly five expected if the two types of insemination were independent events. A test for independence indicates that an insemination by a "first" male significantly reduces, though barely so, the chances of insemination by a "second" male ($X^2 = 3.91$, $.05 > p > .01$).

As mentioned in the Methods and Materials, I recorded the number of flies in each sex which died during a cross in order to study the possible effect upon hybridization of altering the number or sex ratio of the flies. When, for a much larger number of crosses of the same sort (not reported upon here), the number of females inseminated in vials with all flies remaining alive was compared with the number of females inseminated in vials in which one or more flies had died, no significant differences were found.

Two things should be noted about the experiments as a whole. One is the difference between the first and second experiments in frequency of hybridization, especially in the counter-conditioning vials (3% and 22.4%, respectively). The other point is the large difference between the percentage of females inseminated and the percentage of small mass mating vials which yield offspring (21.3 vs. 32.1, respectively, for the controls, and 19.1 vs. 30.2, respectively, for the experimentals). To not determine exactly what percentage of the females is inseminated results in an overestimate of hybridization, since the insemination of just one female can cause a five-pair mating vial to be scored as a mating.

Discussion

Counter-conditioning the young (one- to four-day) *melanogaster* females with *simulans* males had no effect on later isolation, judging from the experiment in which individual females were tested singly. The results of my first experiment, which showed significantly increased isolation (after counter-conditioning) for the five-pair mating vials, is difficult to interpret since the individual females were not tested for insemination, and not enough of these experiments were performed to determine how the time of year might influence these types of crosses (especially since the two experiments were performed in a very different time of the year, March and September, respectively, for the first and second experiments). I have earlier shown (6, 7), in a much more extensive series of experiments, that isolation between these two species can vary widely from one season to another.

When Mayr and Dobzhansky (11) counter-conditioned *D. pseudoobscura* males with *persimilis* females, the males later showed greater isolation from *persimilis* (under poorly controlled conditions); *persimilis* males counter-conditioned with *pseudoobscura* females later showed significantly decreased isolation with *pseudoobscura*. It should be noted that Mayr and Dobzhansky studied counter-conditioning of males, whereas I studied counter-conditioning of females.

Pontecorvo (14) found that once a young *melanogaster* female mates with a *simulans* male, successive matings occur till old age, as though the mating reaction of the young female is not yet fully determined but still liable to conditioning by foreign males. By contrast, I have found that an insemination of a *melanogaster* female by a *simulans* male significantly reduces the chances of an insemination by a second *simulans* male. For different races of *D. paulistorum*, it has been found (12) that previous heterogamic copulations did not change the degree of sexual isolation but that previous homogamic copulations were followed by significantly higher female preferences for homogamic males.

The results presented above may be discussed in light of the relation between the two species in nature. Although there are some differences between the two species as regards their preferences for oviposition sites (16), both *simulans* and *melanogaster* females lay their eggs in rotting fruit, and it is likely that newly emerged flies of the two species are on occasion temporarily close together; it takes an hour or so for the wings to become functional. One would expect, in the light of these experiments, that such early contacts with the other species would have no significant effect on the later discrimination by *melanogaster* females against *simulans* males.

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Ectoparasites and Food Habits of the Opossum, *Didelphis virginiana*, in Indiana

JOHN O. WHITAKER, JR., GWILYM S. JONES, and REBECCA J. GOFF
Indiana State University, Terre Haute, Indiana 47809

Abstract

The major ectoparasites found on 66 opossums in Indiana were four kinds of mites, *Marsupialichus brasiliensis*, *Archemyobia inexpectatus*, *Ornithonyssus wernecki* and *Didelphilicus serrifer*, a chigger mite, *Neotrombicula whartoni*, and the cat flea, *Ctenocephalides felis*. A number of other invertebrates, some parasitic, were found in the fur in low numbers. A large number of kinds of food was found, indicating that *D. virginiana* is opportunistic and will eat many kinds of foods as available. A total of 71 food categories was listed, but mammals, collectively, formed 22.2% of the total volume, followed by birds 21.3%, other vertebrates 9.0%, insects 11.7%, other invertebrates 13.6%, vegetation 19.0% and garbage 3.1%.

Introduction

Hock (7) remarked that the opossum appears to be one of the most heavily parasitized of North American mammals, while Hamilton (6) stated that the opossum is relatively free of arthropod parasites. The most abundant ectoparasite found by Hamilton on over 200 opossums from New York was the tick, *Ixodes cookei*. However, this species occurred on only seven hosts which harbored from 1 to 18 individuals each. Other ectoparasites taken in low numbers were the fleas, *Oropsylla arctomys*, *Chaetopsylla lotoris*, *Ctenocephalides felis*, *Ctenopthalmus pseudagyrtes*, *Orchopeas wickhami* and *Rhopalopsyllus gwyni*. Mites found were *Liponyssus* sp. (identification unclear) and the chigger, *Neotrombicula microti*.

All opossums taken in summer and early fall during a study in Kansas were infested with ticks, *Dermacentor variabilis* (5). The same tick and also a flea, *Opisodasys* sp. were found on the opossum in Missouri (11).

The most comprehensive study of the ectoparasites of *D. virginiana* is that of Morlan (9) who examined 349 opossums and found (Numbers after each parasite represent the number of hosts infested and the total number found):

ANOPLURA: *Hoplopleura sciuricola* (1, 2); *Polyplax spinulosa* (5, 7).

SIPHONAPTERA: *Echidnophaga gallinacea* (33, 322); *Cediopsylla simplex* (9, 12); *Ctenocephalides felis* (133, 615); *Pulex irritans* (1, 2); *Xenopsylla cheopis* (16, 27); *Odontopsyllus multispinosus* (3, 3); *Orchopeas howardi* (31, 80); *Polygenis gwyni* (114, 501); *Leptopsylla segnis* (3, 3).

ACARINA (MITES): *Hypoaspis lubrica* (2, 4); *Haemogamasus liponyssoides* (1, 4); *Androlaelaps fahrenholzi* (31, 222); *A. casalis* (2, 3); *Eulaelaps stabularis* (9, 15); *Echinolaelaps echidninus* (1, 1); *Ornithonyssus bacoti* (24, 206); *O. wernecki* (34, 195); *Cheyletus eruditus* (1, 52).

ACARINA (TICKS): *Ixodes cookei* (5, 8); *I. scapularis* (5, 7); *Amblyomma americanum* (2, 16); *Dermacentor variabilis* (71, 411); *Haemaphysalis leporis-palustris* (2, 2).

ACARINA (CHIGGERS): *Eutrombicula alfreddugesi* (6, 23); *E. splendens* (15, 196).

Other reports of mites on North American opossums are summarized by Whitaker and Wilson (14). These include, in addition to some of the species mentioned above, *Marsupialichus brasiliensis, Haemogamasus hirsutus* and *Archemyobia inexpectatus.*

There are few reports of ectoparasites from opossums from Indiana, but 21 individuals and 4 separate collections of opossum parasites from that state were examined for sucking lice, fleas and ticks by Wilson (15). No lice were found, but fleas included *Cediopsylla simplex* (1 individual), *Ctenocephalides felis* (7), and *Orchopeas howardi* (1). Ticks consisted of 11 specimens of *Dermacentor variabilis,* and 2 of *Ixodes cookei. Marsupialichus brasiliensis* has also been recorded from *Didelphis* from Indiana (4).

Most of the parasites previously reported from the North American opossum are of larger species. There has been little effort to study the smaller forms, especially some of the mites.

Several workers have examined stomachs or scats from the opossum (1, 6, 8, 11, 12, 13, 16), but the data of Hamilton (6), who examined 461 stomachs from New York, were the most extensive. All studies reflect the great diversity in the foods eaten by this species. Hamilton found an overall percent volume of 22.6% mammals, 14.1% fruit, 10.3% earthworms, 9.3% amphibians, 8.1% green vegetation, 7.9% insects, 7.2% birds, 6.0% carrion, 5.6% reptiles and 3.0% mollusks. There is no food habits information available for the opossum from Indiana.

Materials and Methods

Sixty-six opossums were examined for ectoparasites between 1962 and 1976, mostly by direct examination of the hair and skin under a zoom dissecting microscope (10-70X). Parasites were cleared in Nesbitt's solution and mounted in Hoyers solution and the coverslips were ringed with Euparal. Stomach materials from 83 individuals were examined in water, and were identified by comparison with items collected in the field. Visual estimates were made of the volume of each material in each stomach, and the data were summarized as percent volume and percent frequency.

PARASITES:

The major parasites of *Didelphis virginiana* in Indiana are four kinds of mites: *Marsupialichus brasiliensis, Archemyobia inexpectatus, Ornithonyssus wernecki* and *Didelphilicus serrifer*; a chigger: *Neotrombicula whartoni*; and the cat flea: *Ctenocephalides felis* (Table 1).

Archemyobia inexpectatus (Myobiidae) and *Ornithonyssus wernecki* (Macronyssidae) are common North American parasites of *Didelphis* (14).

TABLE 1. *Ectoparasites and other associates of 66 opossums,* Didelphis virginiana *from Indiana.*

Mites (other than chiggers)	Total No. taken	Avg. No. per host	Percentage of hosts infested
Marsupialichus brasiliensis	16,920	256.36	25.7
Archemyobia inexpectatus	4,436	67.21	28.8
Ornithonyssus wernecki	1,138	17.24	39.4
Didelphilichus serrifer	903	13.68	31.8
Zibethacarus ondatrae	259	3.92	4.5
Oribatid mites	27	.41	10.6
Androlaelaps fahrenholzi	9	.14	9.1
Listrophorus dozieri	5	.08	3.0
Anoetidae	3	.05	1.5
Macrocheles sp.	2	.03	1.5
Haemogamasus reidi	1	.02	1.5
Androlaelaps casalis	1	.02	1.5
Lophuromyopus sp.	1	.02	1.5
Ornithonyssus sylviarum	1	.02	1.5
Ornithonyssus bacoti	1	.02	1.5
Laelaps multispinosus	2	.03	1.5
Chiggers			
Neotrombicula whartoni	137	2.08	21.2
Eutrombicula alfreddugesi	2	.03	1.5
Ticks			
Ixodes cookei	4	.06	3.0
Dermacentor variabilis	1	.02	1.5
Fleas			
Ctenocephalides felis	147	2.23	25.7
Orchopeas leucopus	6	.09	3.5
Ctenocephalides canis	3	0.05	3.0
Orchopeas howardi	2	.02	1.5
Ctenopthalmus pseudagyrtes	1	.02	1.5
Chaetopsylla lotoris	1	.02	1.5
Biting Lice			
Trichodectes octomaculatus	1	.02	1.5

Marsupialichus brasiliensis, Fain, 1967 (Labidophoridae, Glycyphagidae), a non-feeding, phoretic mite (hypopus) has previously been reported for North America (4). However, *M. marsupialis* was described from *Didelphis marsupialis* from Surinam in 1972 (3), and in 1973 hypopi from *D. virginiana* from Louisiana were identified by Pence (10) as the latter species. The adult, tritonymph, protonymph and larva of *M. marsupialichus* have been described (3); the hypopus is similar to that of *M. brasiliensis* except that the tibial spine of leg IV is distinctively curved and solenidion w3 is considerably longer than w1. We have examined some of the slides from Pence's Louisiana material, and find them very similar, if not identical, to the Indiana hypopi. Pence (10) suggested, and we concur, that the hypopi and other life stages of *M. marsupialis* and *M. brasiliensis* be further examined and compared with those of *M. andretti,* the other species of *Marsupialichus* described from an opossum.

The only previous description and record of *Didelphilichus serrifer* (Listrophoridae) was from *Didelphis azurae* from Brazil (2); thus, the present occurrence constitutes a new mite record for North America, and also a new host record for *D. virginiana.*

Although a variety of fleas was found, the cat flea, *Ctenocephalides felis*, was the only one of regular occurrence. Seven of nine fleas found by Wilson (15) on Indiana opossums were this species; the others were *Cediopsylla simplex* and *Orchopeas howardi*. The cat flea occurs primarily on domestic cats and dogs. The few records in the literature where dates of collection are given (15) indicate that this may be a winter flea, as the majority of the records fall between September and March. Data collected during the present study support this hypothesis, as 13 opossums collected from April to August had a total of 7 fleas of this species (0.53 per opossum), while 140 were found on the 53 opossums taken from September through March (2.64 per opossum). This difference is significant (Chi-square = 20.74, 1 df). The fact that *C. felis* is the only flea of regular occurrence on the opossum probably reflects its host's close affinity with man and his domesticated animals.

Few ticks were found during the present study; they represented the same two species previously reported on *D. virginiana* from Indiana (15).

The rather large number of parasite species taken and the appearance of a few species normally considered to be host specific on other hosts probably reflect the food habits of the opossum. This species eats a great variety of foods, many of them taken as carrion. We suspect that parasites are more likely to move from a dead and cold host to a carrion feeder than when their normal host is still warm, as would often be the case when a predator kills and eats its prey. During our laboratory studies of dead animals, we have often observed the movement of parasites to the ends of the hairs when the host has become cold. We believe this tendency helps to explain the occurrence of some of the more host specific forms on *Didelphis*, such as *Zibethacarus ondatrae*, *Listrophorus dozieri* and *Laelaps multispinosus*, normally found on muskrats; *Ornithonyssus sylviarum*, normally found on chickens; *Trichodectes octomaculatus*, normally of the raccoon, and *Androlaelaps casalis*, *Orchopeas howardi* and *Haemogamasus reidi*, normally of squirrels. The presence of these species probably indicates that the opossum has recently fed on the respective hosts. That two of the three opossums that harbored *Zibethacarus ondatrae* were the only opossums found to harbor *Listrophorus dozieri* further supports this idea. Only one opossum harbored *Orchopeas howardi* but the same animal was the only one that harbored *Haemogamasus reidi*.

Food Habits

As in previous studies in other areas, a great variety of food items (total of 71 categories listed) was found in the stomach of opossums from Indiana (Table 2). The total volume of mammal remains in stomachs was 22.2%, while birds totaled 21.3%. Amphibians, mostly *Bufo woodhousei* totaled 2.2% of the volume, while reptile (turtle) totaled 0.1%. Carrion totaled 4.9% of the volume of the sample, while unidentified flesh comprised 1.8%. It is likely that much of the vertebrate material listed as bird and mammal remains was carrion, and that it was probably scavenged from highways. Total insect remains

TABLE 2. *Foods eaten by 83 opossums,* Didelphis virginiana, *from Indiana.*

Mammal (Total 22.2% volume)		
Unidentified mammal	4.2	8.4
Blarina brevicauda	3.8	4.8
Microtus ochrogaster	2.7	3.6
Didelphis virginiana	2.5	3.6
Tamias striatus	2.2	2.4
Sylvilagus floridanus	2.1	2.4
Microtus pennsylvanicus	1.5	2.4
Sciurus niger	1.2	1.2
Peromyscus sp.	0.9	1.2
Peromyscus maniculatus	0.7	1.2
Mus musculus	0.2	1.2
Cryptotis parva	0.2	3.6
Bird (Total 21.3% volume)		
Unidentified bird	15.4	22.9
Colinus virginiana	2.4	2.4
Turdus migratorius	1.9	2.4
Domestic chicken	1.3	2.4
Colaptes cafer	0.3	2.4
Other vertebrates (Total 9.0% volume)		
Carrion	4.9	8.4
Bufo woodhousei	2.1	6.0
Flesh, unidentified	1.8	6.0
Turtle	0.1	1.2
Salamander	0.1	1.2
Insects (Total 11.7% volume)		
Carabidae	2.8	10.8
Acrididae	2.7	8.4
Gryllidae	1.9	14.5
Lepidopterous larvae	1.2	13.3
Pentatomidae	0.5	4.8
Gryllacrididae	0.4	1.2
Tettigoniidae	0.4	2.4
Scarabaeidae	0.2	3.6
Muscoid fly	0.2	2.4
Tipulid larvae	0.2	3.6
Scarabaeid larvae	0.2	1.2
Lampyrid larvae	0.1	2.4
Lygaeidae	0.1	1.2
Unidentified Coleoptera	0.1	1.2
Unidentified Diptera	0.1	1.2
Coleopterous larvae	0.1	3.6
Unidentified Hemiptera	0.1	1.2
Acalypterate Diptera	0.1	1.2
Tabanid larvae	0.1	1.2
Tenebrionidae	0.1	1.2
Alleculidae	trace	1.2
Chauliognathus larva	trace	1.2
Nitidulidae	trace	1.2
Formicidae	trace	1.2
Staphylinidae	trace	1.2
Other invertebrates (Total 13.6% volume)		
Earthworm	10.9	34.9
Crayfish	0.7	2.4
Unidentified invertebrates	0.6	6.0
Snail	0.5	7.2

Sowbug	0.5	3.6
Mollusk	0.2	2.4
Slug	0.1	1.2
Spider	0.1	2.4
Vegetation (Total 19.0% volume)		
Unidentified vegetation	13.4	47.0
Wheat seeds	1.2	2.4
Dead leaves	1.1	1.2
Apple	1.1	3.6
Physalis sp. (fruit)	0.8	6.0
Corn	0.4	2.4
Sorghum	0.4	1.2
Grass seeds	0.2	3.6
Phytolacca americana	0.2	1.2
Unidentified seeds	0.2	1.2
Chenopodium seeds	0.1	1.2
Prunus virginiana seeds	trace	1.2
Ambrosia trifida seeds	trace	1.2
Moss	trace	1.2
Garbage	3.1	6.0
Unidentified material	trace	1.2
TOTAL	99.9	

amounted to 11.7% of the volume of food in the sample, and other invertebrates totaled 16.3%. The only important individual item in this last category was earthworms, at 10.9% of the volume. Earthworms were eaten by 34.9% of the opossums in the sample, and were the third most abundant food item, after unidentified bird and unidentified vegetation. Plant items of various sorts totaled 19.0% of the overall volume in the sample, but included the cultivated foods, corn, wheat, and sorghum at low rates (total of 2.0% volume). Garbage was recorded when obvious human food items, wrapping paper, etc., were found in stomachs, but many items in other categories could have been scavenged from dumps, garbage pails, etc.

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